ONTARIO

DEPARTMENT OF LABOUR

MINISTER
THE HONOURABLE CHARLES DALEY

DEPUTY-MINISTER
J. F. MARSH

Steam Plant Accessories

OPERATING ENGINEERS BOARD

TORONTO
1945

Steam Plant Accessories

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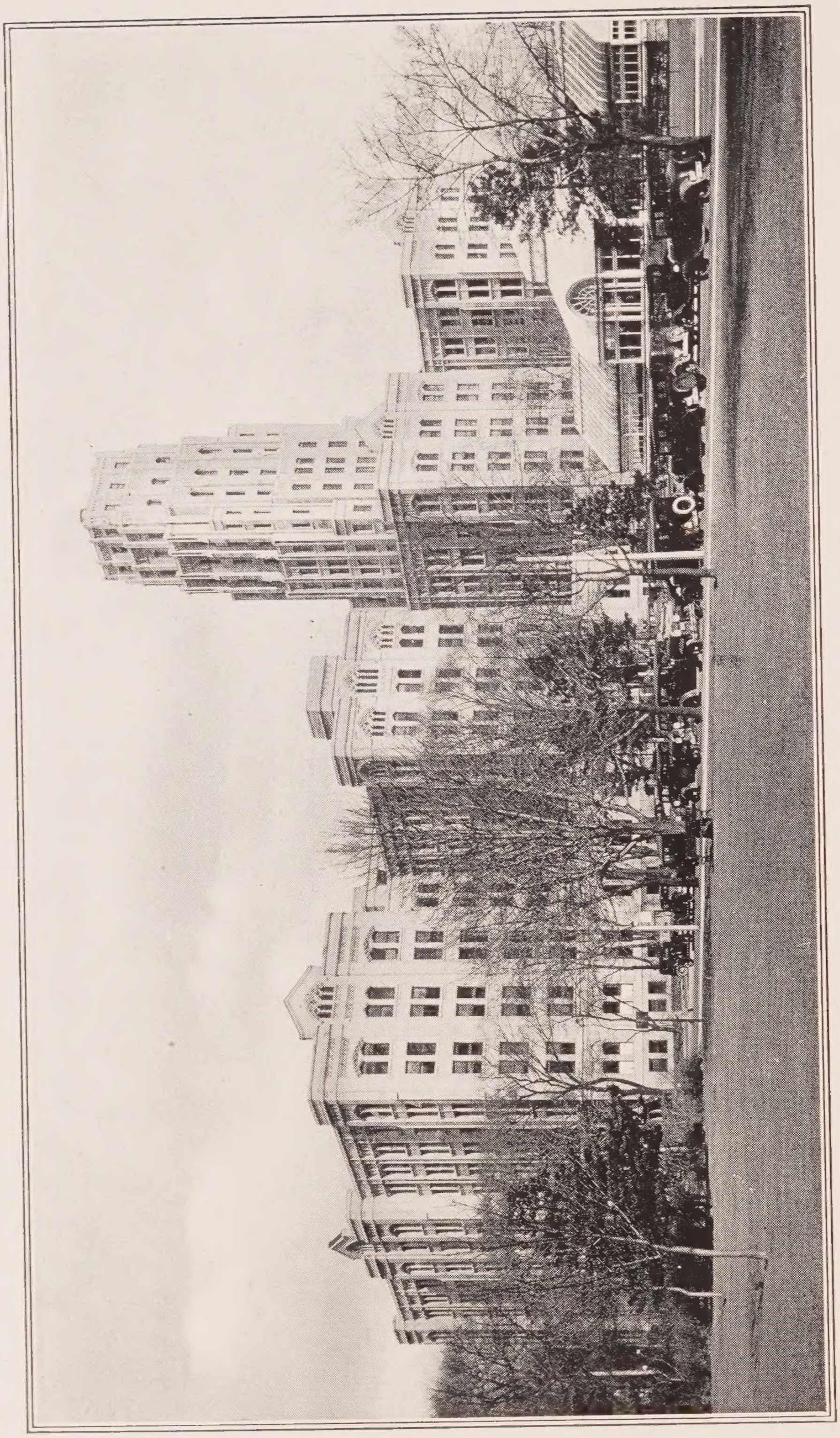


PREFACE

This is the sixth consecutive text-book on power plant operation which the Board has prepared.

It deals with Feed Water Heaters, Feed Water Treatment, Traps, Valves, etc., and completes the engineering course as originally planned.

The series includes the subjects of Boilers, Engines, Turbines, Pumps, Condensers, Refrigeration, Combustion and Steam Plant Accessories.

Written in response to requests from Ontario engineers who were having difficulty in finding published text which was satisfactory for a short and thorough course of study, the aim of the Board has been to present in a compact and simple form the fundamental knowledge required by the power plant operator for every-day application.

Much time has been given to the compilation of these books and it now remains for the engineer to take advantage of them.

There is a high standard of power plant engineering in Ontario. Let us maintain this standard and in so doing advance employee and employer alike.

THE BOARD OF EXAMINERS,
OPERATING ENGINEERS,
EAST BLOCK, PARLIAMENT BUILDINGS,
TORONTO.

INDEX

Steam Plant Accessories

Steam Traps

Steam in pipe lines will contain a certain amount of moisture. This moisture is present for two reasons, firstly, due to priming of the boiler, and secondly, due to condensation of a certain part of the steam by coming in contact with the cool surface of the pipe. The amount of moisture will vary greatly owing to different conditions. It will be comparatively small in high pressure steam lines where there is a rapid flow of steam and the pipes are well insulated with suitable pipe covering, while the greatest amount of moisture will be found in heating systems where an effort is made to condense all the steam in radiators. In the first instance moisture is very objectionable as it is liable to cause water hammer, and if it reaches the engine, retards the working of the piston and is liable to knock the piston head out. In the second case unless the water is removed the pipes will become filled with water and retard the flow of steam. Superheated steam will contain no moisture but the pipe lines should be drained as water is liable to collect in them when the steam is shut off, particularly if the valves are not absolutely tight.

It will be seen that in all cases it is necessary to remove the water. This may be done by the simple method of placing drain on the bottom of the pipe lines, opening them by hand and allowing the hot water to run out and go to waste. This is a very extravagant method as hot water contains much heat.

To remove the condensate and return it to a heater or the boiler where it can be used over again without releasing the steam, the steam trap has been invented. There are a great number of different designs on the market.

Thermostatic Trap

Fig. 1 is a sectional view of the Webster Thermostatic valve.

The Webster thermostatic valve is used principally on small units of radiation, is adjustable and automatic, permitting water and air to pass but expanding when the plug is surrounded by steam, causing it to seat and preventing waste of steam to the return. This valve is intended for fairly constant low pressure.

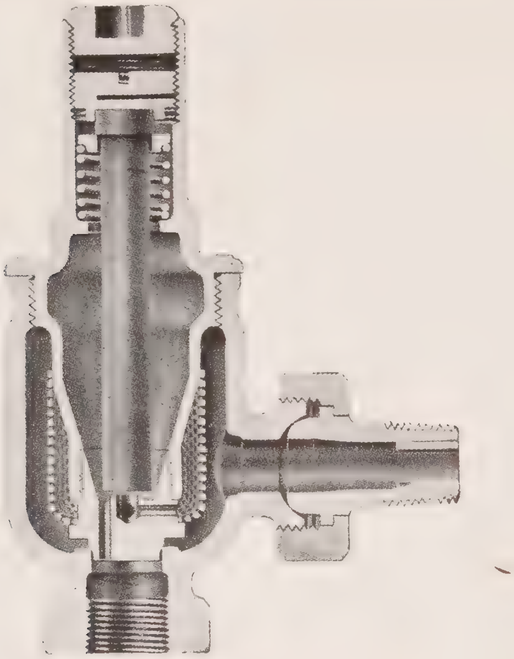


Fig. 1. Webster Thermostatic Trap.

Fig. 2 shows a sectional view of the Dunham trap used on radiators.

The disc for all Dunham traps is constructed of two corrugated members made of special composition phosphor bronze, formed under pressure. The curves of the corrugation are designed to distribute uniformly the motion incidental to the disc operation. The disc contains a volatile fluid compounded to respond to a wide range of temperature. This fluid is hermetically sealed within the disc. The disc is permanently adjusted in the cover at the factory and its setting should not be changed.

When it is installed the disc is subject to the same conditions of pressure and temperature that exist within the radiator, and its operation is controlled by these conditions.

As steam enters a cold radiator it forces the cool air which is in the radiator, out through the trap into the return piping. In warming the radiator the steam gives off heat and in doing so condenses to water. The water which is heavier than steam falls to the bottom of the radiator and flows to the trap through which it also passes into the return piping. After forcing out the air, the steam fills the radiator and follows the water to the trap, which, in the presence of steam, automatically closes because the steam is hotter than either the air or water. The heat of the steam vaporizes the fluid within the disc and creates a gas which expands the disc, closing and holding the valve against its seat with a positive pressure, thus trapping the steam within the radiator.

The radiator now thoroughly filled with steam gives off heat, condensing the steam at a uniform rate, and the water of condensation which is cooler than the steam, flows in a steady stream to the trap which it slightly chills, causing it to open, allowing the water to pass out.

The trap adjusts itself to a position corresponding to the water temperature, just as a thermometer does to the room temperature, and permits a continuous flow of water from the radiator.

The operation of a trap attached to a radiator has been described. The traps operate in a similar manner to trap steam when used on any other form of heating surface or to drip piping. The air and water, which are both cooler than steam, cause the trap to open and steam causes it to close. The operation of the trap is not that of alternately opening and closing; it adjusts itself slowly like a thermometer to the temperature conditions present and permits a continuous flow of air and water at a rate to keep the heating surface free from air and water and full of steam, without waste of steam.

Fig. 2-A shows another type of thermostatic steam trap, known as the Sarco.

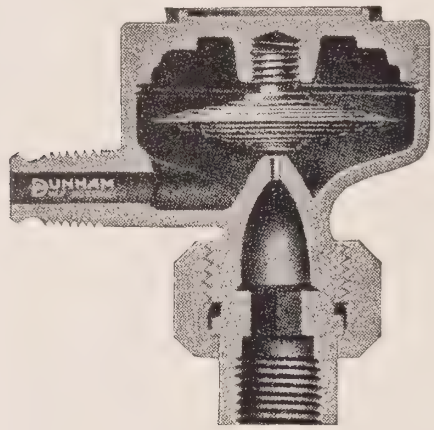


FIG. 2. Dunham Thermostatic Trap.

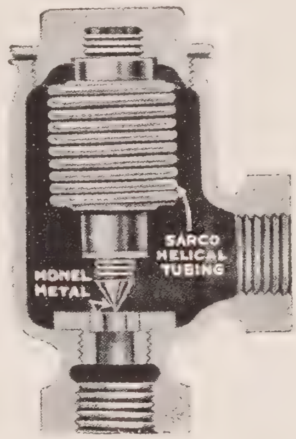


FIG. 2-A Sarco Thermostatic Trap.

Bucket and Float Traps

To handle a large volume of condensation the float trap or bucket trap is usually used. The principle involved in both types is practically the same. In the float trap the hollow ball floats on the return condensate water which flows by gravity from the drains on the steam lines to the body of the trap. This float being attached to a suitable lever mechanism, operates a valve on the outlet of the trap. As the water level rises the float rises, opening the valve allowing the water to be discharged and when the level of the water drops, the float is lowered and closes the valve.

A vent is placed on the top of the trap to allow for the escape of any air which may collect.

In the operation of traps, care should be taken that the valve is always tight; otherwise, steam will escape through the trap and go to waste.

There should always be a by-pass pipe around the trap, fitted with the necessary valves, so that the trap may be opened and examined at any time. These traps should be connected to pipe lines by drains leading from their lowest points. Very often the traps are used in conjunction with steam separators and connected by a drain leading from the bottom of the separator, where the water settles after being separated from the steam.

Usually these traps are made to discharge into feed water heaters and from there the condensate is returned to the boiler by means of the feed pump.

Fig. 3 illustrates a float trap of the lever type. The rising and falling of the float opens and closes the valve in proportion to the rate of discharge.

Unless float traps are well made and proportioned, there is a danger of considerable steam leakage through the discharge valve, due to unequal expansion of valve and seat and the sticking of moving parts. The discharge from a float trap is usually continuous, since the height of the float, and consequently the area of the outlet, is proportional to the amount of water present. When the trap is working lightly, this adjustment is apt to throttle the area and create such a high velocity of discharge as to cause a rapid wear of valve and seat. This defect is more or less evident in all steam traps discharging continuously. For this reason all wearing parts should be accessible and readily replaceable.

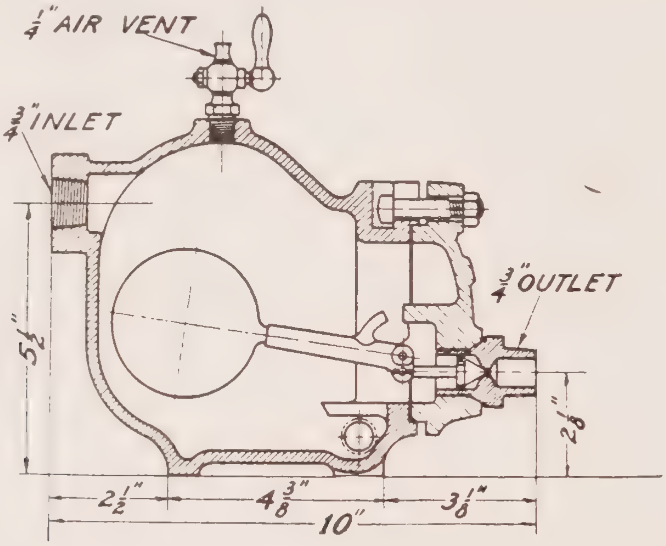


Fig. 3. A typical Float Trap, the valve being operated by a hollow ball and lever.

A section through one of the many designs in bucket traps, is shown in Fig. 4. The water of condensation enters at A, filling space D between the bucket E and the walls of the trap, which causes the bucket to float. When the bucket floats, valve V is forced against its seat. The water rises until it overflows the edges of the bucket and causes it to sink, thereby opening valve V. The steam pressure acting on the surface of the water forces it up through ring H and out discharge opening G. When the bucket is emptied, it floats again, closing valve V and the cycle is repeated. The discharge from this type of trap is intermittent.

Operation of the Armstrong Steam Trap

The Armstrong trap operates through the rise and fall of an inverted submerged bucket, the motion of this bucket being imparted to the valve through a compound leverage.

Referring to Fig. 5, the bucket hangs with its open end down, directly over the inlet which is centrally located in the bottom of the trap. As the outlet of the trap is at the top, the body must be full of water before any flows out. The trap is shown with the bucket in its lowest position with the valve open. Water entering the trap flows into the open end of the bucket, then out around the bottom, up and through the valve. This flow will continue so long as water enters the trap.

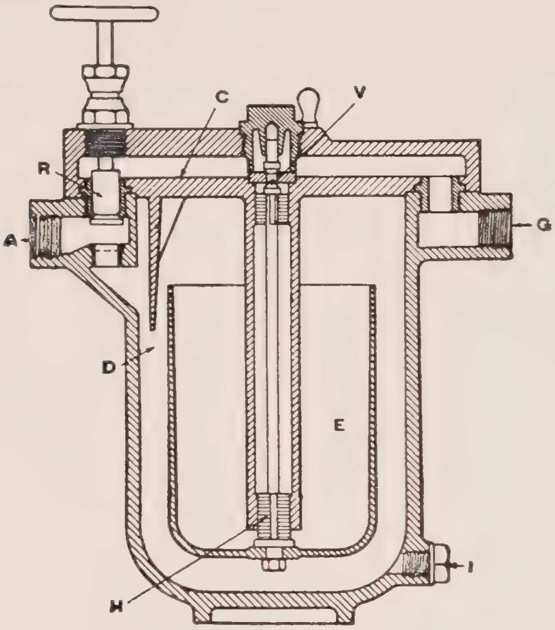


Fig. 4. Bucket Trap.

Suppose the system is drained of water and steam enters the trap. It will rise up into the bucket displacing the water which will flow out of the discharge. Steam will accumulate in the bucket until it becomes buoyant, when it will quickly rise and close the valve preventing a further discharge. The bucket is so weighed that it will float when about three-fourths full of steam.

Referring to illustration, it is evident that, with the valve closed, the body of the trap full of water and the bucket containing steam, nothing can enter the trap until the volume of the contents is reduced. This occurs by the condensation of the steam in the bucket. As this steam condenses its volume is reduced and either steam or water enters the trap to take the place of the steam condensed. If steam enters it merely rises up into the bucket taking the place of that condensed.

If water enters it also takes the place of the condensed steam and thus the volume of steam in the bucket becomes less. As this volume diminishes, the buoyancy of the bucket becomes less, until finally the volume becomes so small that the buoyancy is overcome by the weight of the bucket, which quickly sinks to the bottom and, through the compound leverage, pulls the valve from its seat and the discharge takes place. This completes the cycle of operation which is repeated alternately as steam and water enter the trap.

In the top of the bucket there is a small vent hole. Air entering the trap rises up into the bucket, the same as steam. This air, instead of condensing, passes through the vent hole and accumulates in the top of the trap, displacing the water which, in turn, enters the bucket to take the place of the air. Thus the bucket loses its buoyancy and sinks, opening the valve, and the air that has lodged in the top of the trap is discharged.

The small amount of steam that passes through the vent hole is condensed in the surrounding cooler water and never reaches the top of the trap.

The constant agitation of the water above the vent by the steam and air passing through the hole prevents any sediment from settling in and clogging it.

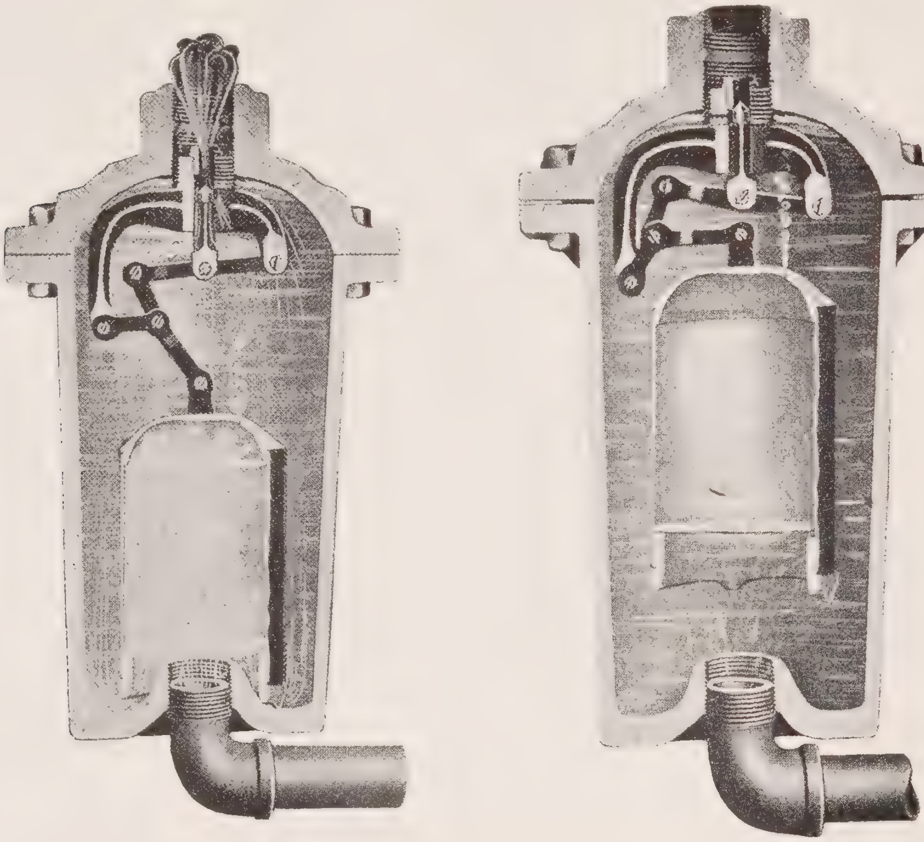


Fig. 5. Armstrong Trap showing the valve open and the valve closed.

Dumping Traps

Another type of trap, different in construction but doing the same work, is known as the dumping trap. There are a number of different designs of this type but the principle is the same in all. In the Bundy trap (see Fig. 7) the condensate is received into a hollow spherical shell, while in the Cole and the Morehead and others, a hollow cylinder is used as the receptacle of the condensate (see Fig. 8).

Dumping traps are frequently used for returning the condensate direct to the boiler without using a boiler feed pump.

Return Traps

Feeding boilers is only one, though perhaps the most important, application of return traps. Among the many other uses are returning condensation of distant buildings to the boiler house, draining vacuum systems, pumping and metering.

All return traps operate on the same principle. From the diagram in Fig. 6 this operating cycle can be easily seen. A is a boiler drum and B a tank 4 to 6 ft. above the water level

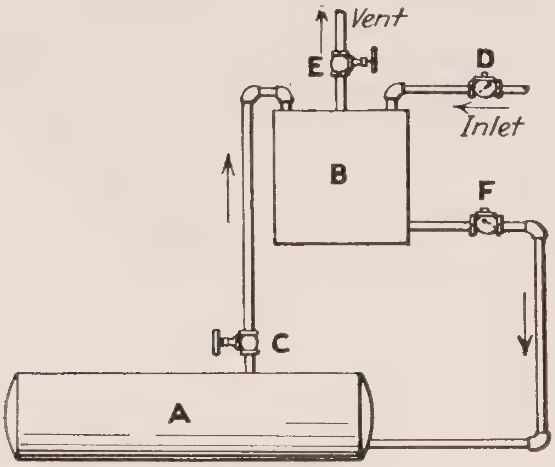


FIG. 6. Diagram showing principle of Return Trap.

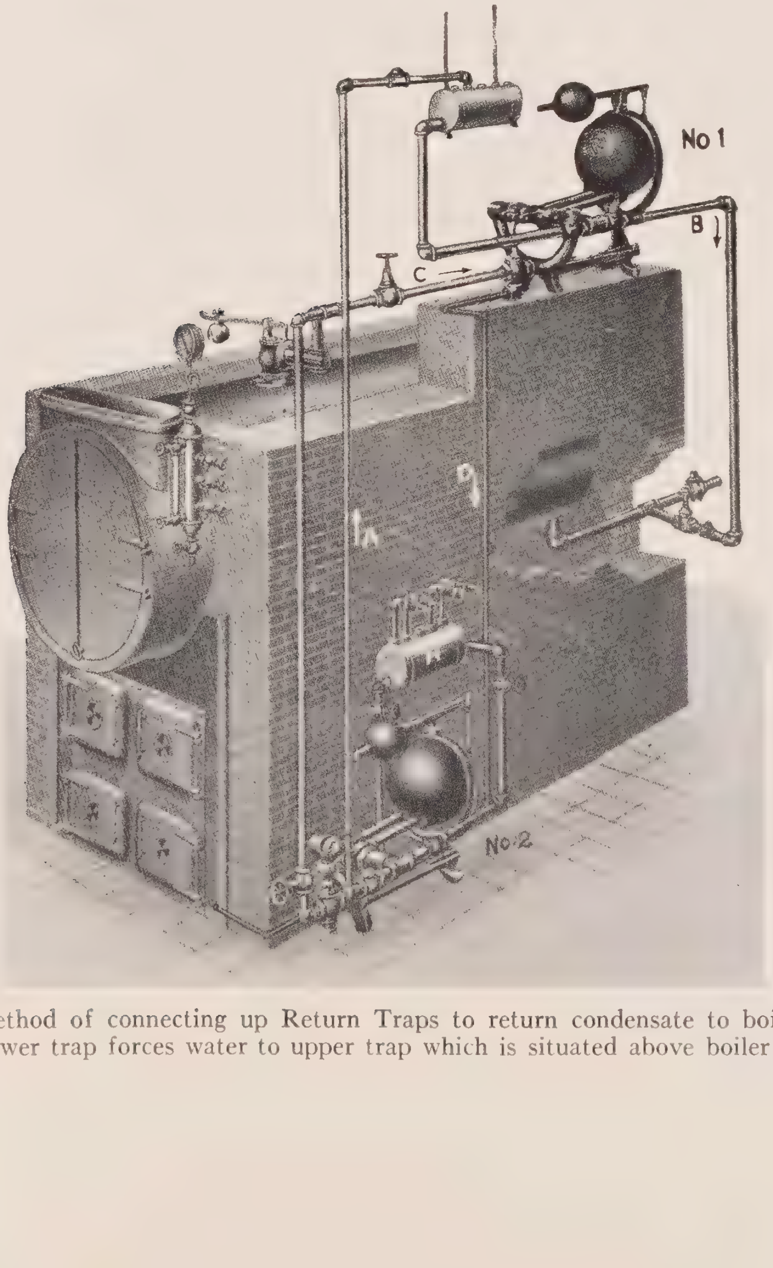


FIG. 7. Method of connecting up Return Traps to return condensate to boiler. (Note: Lower trap forces water to upper trap which is situated above boiler level.)

in the boiler drum. Condensate returns through the check valve D and into the tank B, valve E in the vent line being open. When tank B is full, valve E is closed and steam valve C is opened, admitting boiler pressure to the space above the water surface in the tank. This forces check valve D to close and check valve F to open, allowing the water in B to flow down into the boiler drum.

To feed a boiler the trap must be above the boiler drum. In actual return traps, valves C and E are automatically operated when the tank becomes full and again when it becomes empty. Check valves D and F are used with the actual trap as indicated in Fig. 6, though they frequently are not a part of the trap when it is purchased.

All condensate and drains should first be collected in a receiving tank. This gives the condensate a place to flow while the return trap discharges into the boiler. The receiver should be so placed that all the water to be fed to the boiler will drain into it. In most boiler rooms it will be necessary to elevate the water from the receiver tank to the return trap above the boiler. When pressure in the return system is too low to lift the water, a second return trap is installed to raise it to the return trap above the boiler, (see Fig. 7) While the illustrations shows the lower trap located in the boiler room, this location is not arbitrary. Conditions in many plants require the "lifting trap" to be placed hundreds of feet away from the boiler room. In this event the live steam supply is generally taken from a conveniently located line. Where heating coils are scattered, owners can use two or more lifting traps, arranged to empty into one return trap in the boiler room, but the boiler trap must be large enough to accommodate the output from all the lifting traps.

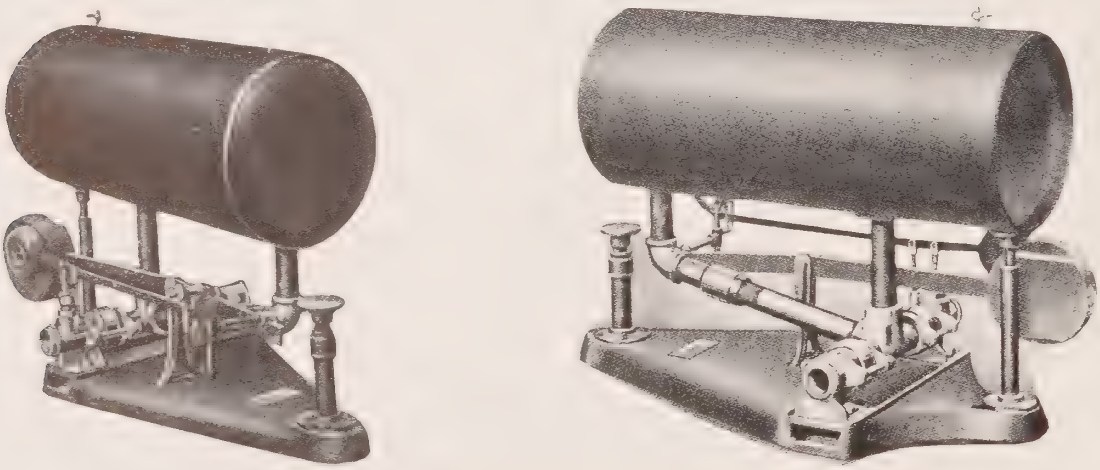


FIG. 8. Cylinder Type of Dumping Trap.

Advantages of Return Traps

Advantages claimed for return traps over steam or motor-driven pumps are: first, a saving in heat because the condensate may be kept at a higher pressure and temperature than is possible when this condensate is returned to an open hotwell; second, little steam is used for pumping and its heat (except that lost by radiation) is returned to the boiler; third, moving parts are few and simple.

Capacity depends on the size of inlet and discharge, the resistance to flow of water offered by the trap passages, and the difference between actual steam pressure and discharge pressure.

In the case of a return trap feeding a boiler, the elevation of the trap above the water level of the boiler provides the head for forcing the water into the boiler drum and greatly influences the capacity of the trap.

The frequency with which the trap operates depends on the volume of the trap tank; with a large tank the trap operates less frequently. Traps are usually rated for from 25 to 60 operations per hour. Traps for larger capacities usually operate less frequently.

Return traps are built in sizes ranging from ½ in. to 4 in. diameter of the discharge valve. A 4-in. trap set 4 ft. above the boiler will have a capacity of about 28,000 lbs. per hour. Traps are built for pressures up to about 250 lbs. per square inch.

Return traps may be classified as: (1) tilting traps; (2) float traps. In the tilting trap the receiver tank is mounted on trunnions so arranged that when the trap is filled with water it tilts, thereby operating the vent and steam inlet valve. In the float trap a float-operated lever operates the valves. In both types the valves are outside of the trap tank, easily accessible for grinding or other repairs.

Fig. 8 is a longitudinal view of a typcial tilting trap. The tank is supported on a hollow Y-casting or pipe fittings which terminate in a hollow trunnion about which the tank tilts. In the illustration the tank is empty and in a horizontal position, held in this position by a counterweight. In the horizontal position the vent valve is open and the steam valve closed. When the tank is full, the counterweight overbalances and the tank tilts, closing the vent valve and opening the steam valve. Condensate enters and discharges through the hollow trunnion and casting. Steam enters through the centre standpipe and goes nearly to the top of the tank. This pipe also carries the vented steam. Operation of the linkages for opening and closing the vent and steam valves is obvious from the drawings.

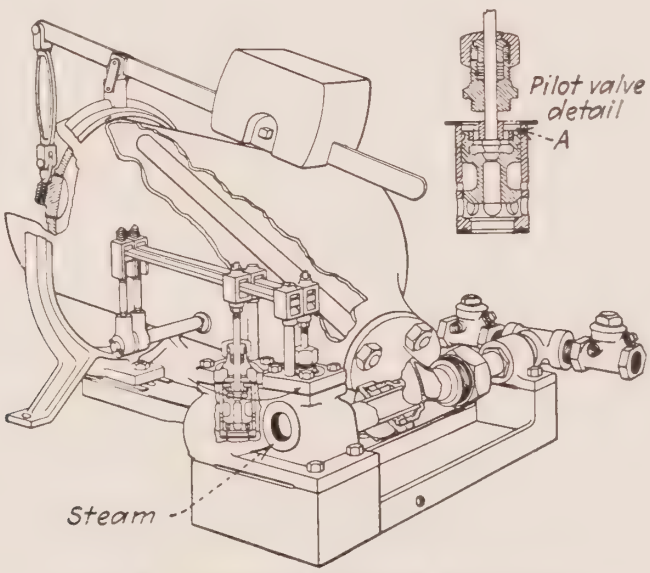


FIG. 9. Dumping Trap using Pilot Valve.

Some manufacturers use pilot-operated valves on their traps. Fig. 9 shows a trap equipped with a pilot-operated valve, the enlarged cross-section showing details of the valve mechanism. The main valve is held open by pressure under the valve disk. When the pilot valve is closed, pressure builds up in space A above the main valve; forces the main disk shut. When the trap opens the pilot valve, pressure is relieved in space A and the steam pressure under the main disk forces the valve open. Another valve arrangement is shown in Fig. 10. Here when the trap tilts, a yoke operates the vent valve and a primary steam valve, admitting steam to the trap tank. As soon as the pressure in the tank has built up to within 15 lbs. of the initial pressure, the unbalanced pressure opens the secondary steam valve. When the trap is emptied the yoke closes both steam valves and opens the exhaust.

When return traps are used to return condensate from high-pressure equipment such as high-temperature cookers, laundry equipment, etc., the condensate is discharged by the non-return traps at a temperature corresponding to the steam pressure. If full thermal advantage is to be obtained in the use of return traps, pressure in the condensate return mains should be kept as high as possible to keep the condensate from flashing into steam. Of course, a certain pressure drop must be permitted to cause the flow of condensate to the receiver. To maintain this pressure a safety or relief valve should be installed on the trap vent, adjusted to operate at a pressure low enough to permit condensate to drain into the trap.

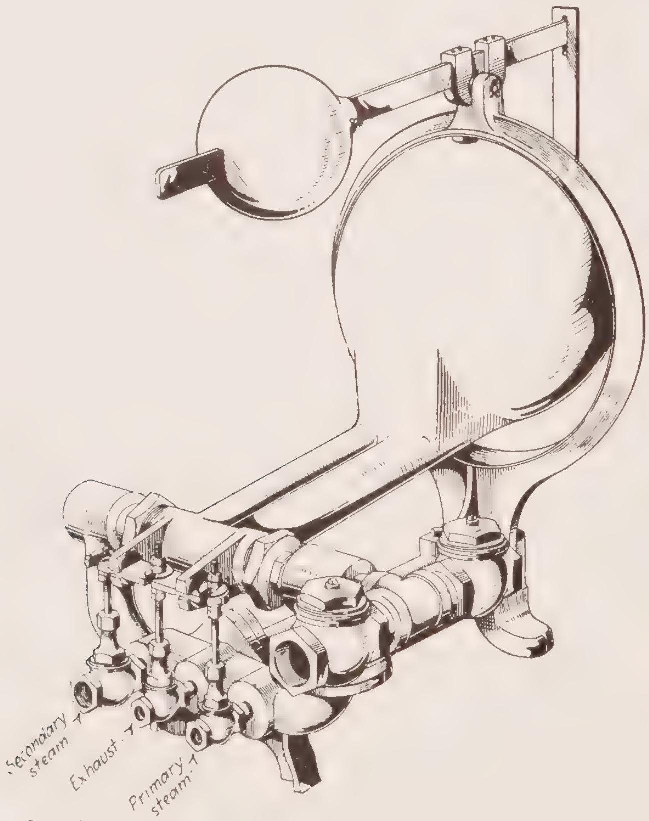


Fig. 10. Another Pilot Valve arrangement used on Dumping Traps.

Economical and satisfactory performance of return traps depends upon keeping the valves steam-tight. A tight trap can be used as a meter by installing a counter.

Much attention has been given to the design of stuffing box and trunnion bearings. Stuffing boxes must be reasonably tight, while at the same time offering as little friction as possible so that the trap will tilt freely when the water level reaches the desired level in the trap tank. Some manufacturers use ball bearings on the trunnions; others use nickel-plated sleeves.

Each manufacturer has his own particular kind of packing which he feels is best for his trap. In general, it is best to follow his recommendations, both as to kind of packing and directions given for installation. Too frequent operation of the trap will cause bearing and packing wear, whereas too infrequent operation of the trap may result in a sticking trunnion.

Non-Tilting Return Traps

The non-tilting return trap operates on the same general principle as the tilting trap, but the trap tank remains stationary. A float inside the tank is connected to a lever arm which operates the steam and vent valves.

Fig. 11 shows the valve-generating mechanism of a non-tilting float-operated return trap. The float in the trap body operates the lever A. The lever A engages with rack B, moving it to a horizontal position just before the trap becomes full or empty. As the rack moves past the horizontal, weight C rolls to the other end and its impact turns the rack, operating the steam and vent valves through lever D. A somewhat similar valve-operating mechanism is used in another trap, except that a weight at the top end of a vertical lever is substituted for the rack and rolling weight.

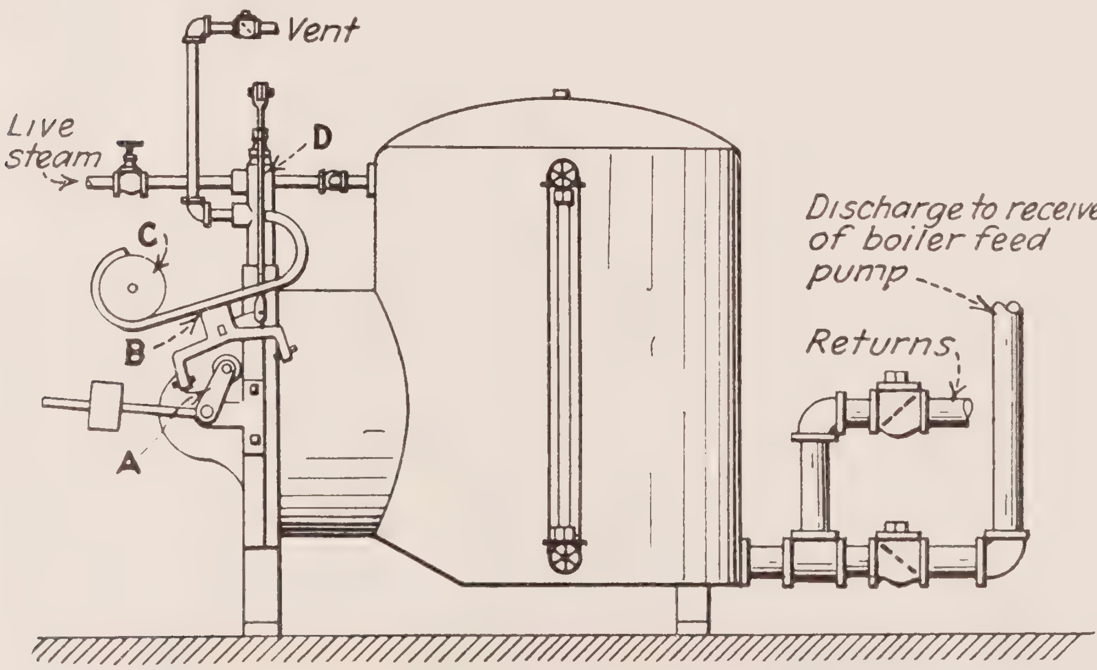


FIG. 11. Non-Tilting Type of Return Trap.

The Steam Loop

Another method known as the steam loop is sometimes used whereby no traps are required.

Fig. 12 illustrates the general arrangement and operation of a simple steam loop for returning drips to the boiler B from a separator T in the steam line S that is supplied out of the same boiler. The principal parts are the "horizontal" C which acts as a condenser and receiver; the riser R which connects the drain pipe of the separator with the top of the horizontal; and the drop leg D which connects the lower end of the horizontal with the feed connection of the boiler.

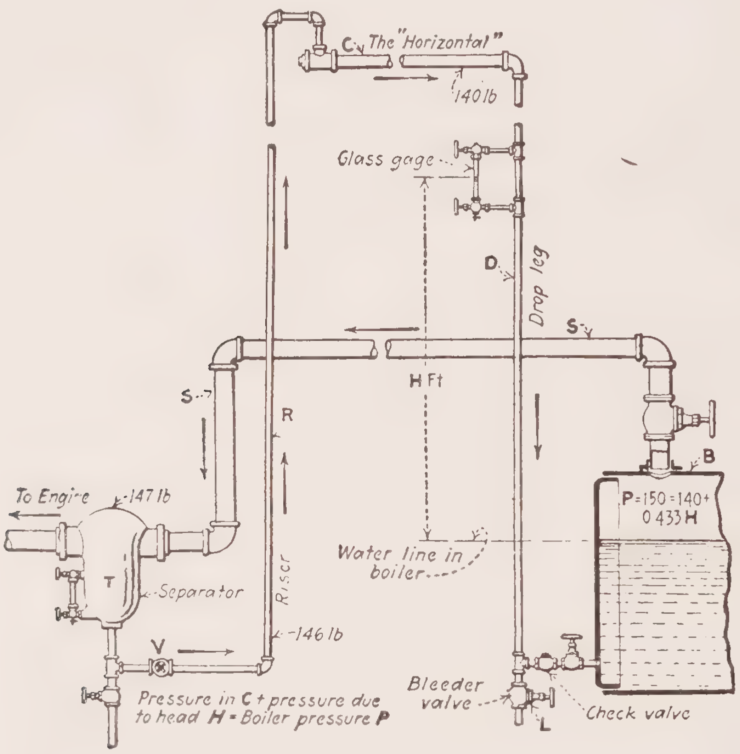


Fig. 12. Steam Loop, sometimes used in returning condensate to boiler. By this method no pumps or traps are used.

Circulation is first established by opening the bleeder valve L at the foot of the drop leg D.

Then with the valve V at the foot of the riser R partly open, water in the separator and riser R is discharged to C and drained off at L. When steam appears, the valve L is closed. The water then discharged from the separator is delivered to the riser R in form of a spray that is gathered in the horizontal C from which it is drained into the drop leg D and in which a head H becomes built up. When the pressure due to the head H plus the pressure in the horizontal becomes greater than the boiler pressure, water in the drop leg will be delivered to the boiler when there is additional building up of the head in D sufficient for overcoming pipe friction and opening the check valve.

The density of the spray must be little enough for the pressure in the riser to raise the spray and deliver it against the pressure in the "horizontal", and the lower this pressure the higher must be the Head H for effecting discharge to the boiler. Since each foot head of water exerts a pressure of about 0.433 lb. per sq. in., then when P is boiler pressure, lb. per sq. in., H the head in the drop leg in feet, and C the pressure in the horizontal, to balance the pressure in the boiler requires $P = C + 0.433\ H$. Where, as indicated, $P = 150$ and $C = 140$ lb. per sq. in., $150 = 140 + 0.433\ H$ and $H =$ about 23 feet.

When the pressure C depends on condensing, as in the simple steam loop, it will be variable and in place of a "horizontal" acting as a condenser, the Holly loop employs a vertical receiver in which the pressure is maintained constant by bleeding the receiver with a reducing valve, the discharge from which may be turned into a feed-water heater or utilized otherwise.

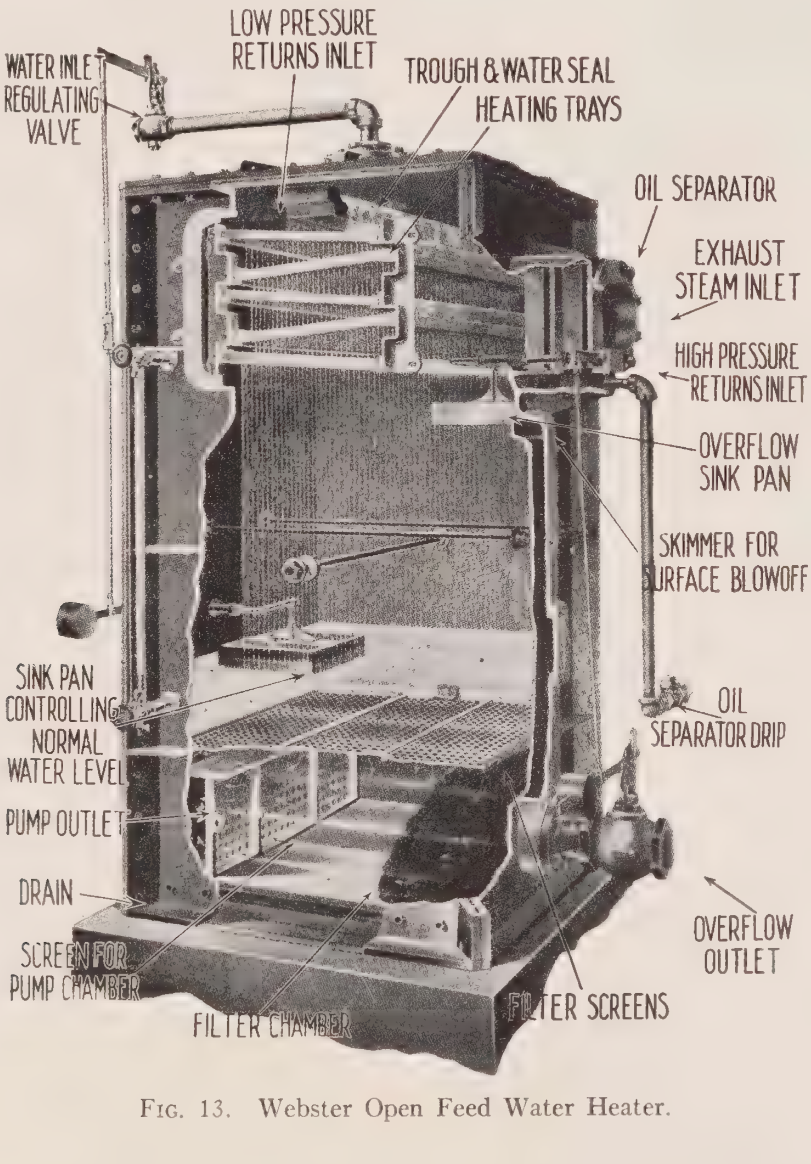


FIG. 13. Webster Open Feed Water Heater.

Feed Water Heaters

Supply water to boilers is either heated in feed water heaters by exhaust steam, which would otherwise go to waste, or by economizers placed in the hot flue gases after they leave the last pass of the boilers.

The economy of feeding heated water to boilers can be seen by studying the steam tables. For instance, if a boiler were fed with water at a temperature of 60 degrees and delivered steam at 150 pounds gauge pressure, it would have to deliver to each pound of steam:

$$1193 - (60 - 32) = 1165 \text{ B.T.U.'s.}$$

While if the feed water was raised to a temperature of 200 degrees before entering the boiler, each pound of steam would require:

$$1193 - (200 - 32) = 1025 \text{ B.T.U.'s.}$$

Therefore, the difference of heat per pound of water, required from the boiler in the second case as compared with the first would be:

$1165 - 1025 = 140$ B.T.U. and the percentage gain:

$$\frac{140}{1165} \times 100 = 12.81\%.$$

There is, therefore a gain of 12.8 per cent in heat required by the boiler, by using exhaust steam which might otherwise go to waste.

This can be put in the form of a formula, as

$$\text{per cent gain} = \frac{T - t}{H - t} \times 100$$

in which T = heat units per pound of feed water above 32° F. after passing through the heater

t = heat units per pound of feed water above 32° F. before passing through the heater

H = heat units above 32° F. of steam at boiler pressure

$$\frac{(200 - 32) - (60 - 32)}{1192 - (60 - 32)} \times 100 = 12.81$$

Feed-water heaters may be classified as exhaust steam heaters and economizers. Exhaust steam heaters may be sub-classified as open and closed.

Open Heaters

In open feed-water heaters the water is heated by direct contact with the steam. This may be accomplished in a variety of ways; by the spray, overflowing trays or an umbrella.

If there is a sufficient amount of exhaust steam, the water may be heated to boiling point. However, with ordinary power plant conditions, where the amount of exhaust steam supplied by the auxiliary machinery is but a small percentage of the amount of steam delivered from the boilers, this high temperature is usually not obtained. The open feed-water heater should be placed at least four to five feet above the boiler feed pump, so that the hot water will flow by gravity to the suction valves, whence the water is pumped to the boilers. Most open feed-water heaters are provided with an oil extractor for removing oil from the exhaust steam, so that it may not be sent to the boiler, therefore, in installing an open feed-water heater, sufficient clearance should be left for the removal and cleaning of the filters or trays, as the case may be.

Well known open feed-water heaters are the Webster and the Goldie and McCulloch, which are especially adapted for the removal of oil. They are shown in the accompanying illustration, see Figs. 13 and 14. See also Cochrane heater, Fig. 45.

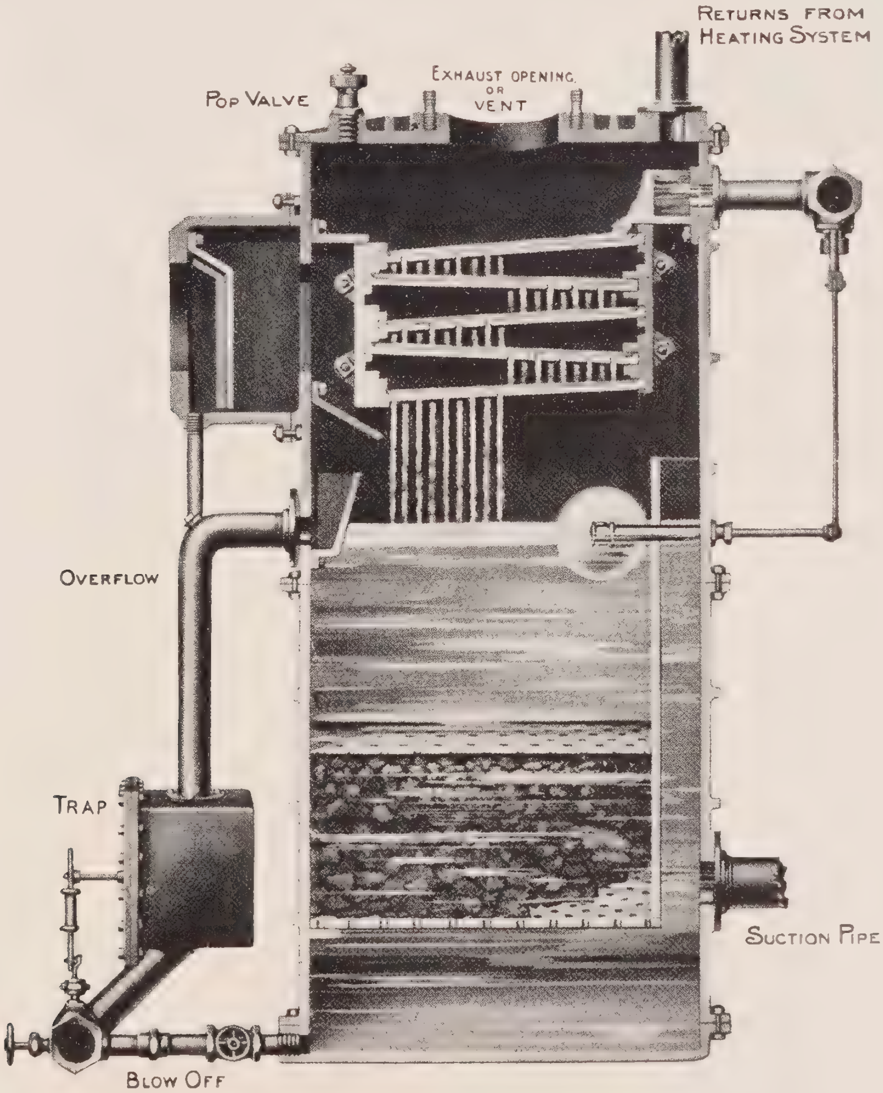


Fig. 14. Goldie & McCulloch Open Feed Water Heater.

From a study of the diagram it is quite apparent that the object of the heater is to receive all the returns from heating system or other sources, and the exhaust from any auxiliary machinery such as feed pumps, fan engine and any other apparatus using steam that, were it not for the heater, would go to waste.

The piping is so arranged that all return water is led in at the top of the heater, where it falls on a series of perforated trays and leaves them in the form of a rain. The exhaust steam that heats the water enters the heater below the trays and travels upward and thus mixes intimately with the descending water, thereby heating it.

There is always a certain amount of loss in return water owing to blowing off of the boiler or any other use of the water, or leaks. It is, therefore, always necessary to provide for makeup water. As can be seen in the diagram, a make-up water pipe enters the top of the heater. On this pipe is a valve, controlled by a lever mechanism which is attached to a float that floats on the surface of the water in the heater and always keeps it at a constant and predetermined level. To prevent heaters from becoming flooded an overflow is provided.

A filter chamber is provided at the bottom of the heater for the purpose of extracting any impurities from the water before it leaves, near the bottom of the heater, to flow to the suction of the feed pump. An open vent or slow pressure relief valve should always be attached to top of heater to prevent pressure building up in the heater and thus causing an explosion.

Closed Heaters

Closed heaters are designed for carrying the exhaust steam either through the tubes, or surrounding the tubes. In the former, the shell, which is either made of cast iron or riveted steel plates, must be of considerable thickness so as to withstand boiler pressure, provided that the feed pumps discharge through the heater. In the other type of closed heater, the shell may be made of light material, as it withstands no pressure other than that of the exhaust steam.

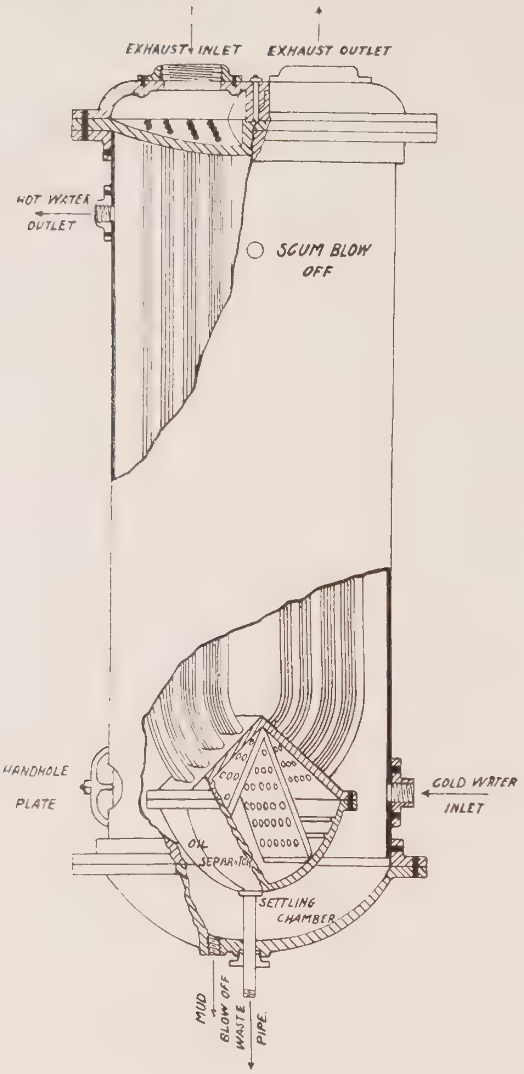
The advantage of the closed heater over that of the open type is that the feed water can be pumped through it, thus the pump handles cold water, whereas with the open heater, the pumps have to be especially fitted for hot water.

There is also the advantage that the exhaust steam, which may contain considerable oil, does not mix with the feed water and, therefore, there is less danger of oil entering the boiler. Oil should never be allowed in the boiler as it will collect on the plate, which may as a result become overheated and destroyed. Oil is also liable to cause foaming.

Closed heaters have to be provided with drains and mud-blow-offs, the drains to take away water of condensation and oil extracted from the exhaust steam, the mud blow-offs for removing the settlings from the feed water.

There are two types of closed feed water heaters. Fig. 15 illustrates the steam tube type in which the steam passes through the tubes and the water surrounds them, while Fig. 16 illustrates the water tube type, in which the water passes through the tubes and the steam surrounds them.

All heaters, either open or closed, should be by-passed with sufficient valves, that is, provision should be made so that the exhaust steam may pass through these heaters or



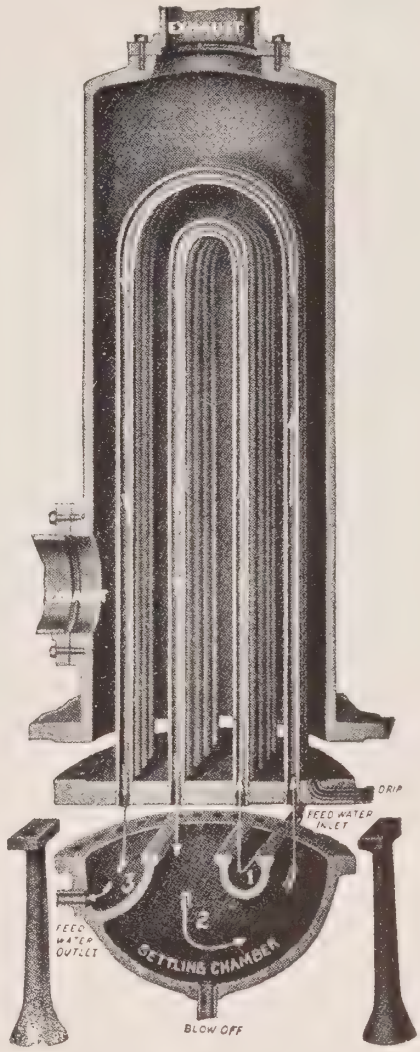


FIG. 15. Steam Tube Type of Closed Feed Water Heater. (In this type the steam passes through the tubes).

FIG. 16. Water Tube Closed Feed Water Heater. This type differs from Fig. 15 in that the water passes through the tubes.

directly to the atmosphere. The heaters may also be provided with vent pipes connected to the atmospheric exhaust pipe, to carry away air and vapor.

Gebhardt in his book "Steam Power Plant Engineering," gives the following summary of the distinguishing features of open and closed heaters.

Open Heater	Closed Heater
EFFICIENCY	
With sufficient exhaust steam for heating the feedwater may reach the same temperature as the steam.	The maximum temperature of the feedwater will always be 2 degrees or more lower than the temperature of the steam.
Scale and oil do not affect the heat transmission.	Scale and oil deposit on the tubes and the heat transmission is lowered.

Open Heater (Continued) / **Closed Heater** (Continued)

PRESSURES

Open Heater	Closed Heater
It is not ordinarily subjected to much more than atmospheric pressure.	The water pressure is slightly greater than that in the boiler when placed on the pressure side of the pump as is customary.

SAFETY

Open Heater	Closed Heater
Sticking of the back pressure valve may cause it to "blow up" if provision is not made for such an emergency.	It will safety withstand any pressure likely to occur.

PURIFICATION

Open Heater	Closed Heater
Since the exhaust steam and feedwater mingle, provision must be made for removing the oil from the steam.	Oil does not come in contact with the feedwater.
Scale and other impurities precipitated in the heater are readily removed.	Scale is removed with difficulty.
Dissolved gases are removed if heater is properly ventilated.	Does not remove dissolved gases, unless vented to lower pressures.

LOCATION

Open Heater	Closed Heater
Must always be placed above the pump suction and on the suction side.	May be placed anywhere on the pressure side of the pump.

PUMPS

Open Heater	Closed Heater
With supply under suction, two pumps are necessary and one must handle hot water.	One cold-water pump is necessary.

ADAPTABILITY

Open Heater	Closed Heater
Particularly adaptable for heating systems where it is desired to pipe the "returns" direct to the heater.	Vacuum or primary heaters are usually of this type. Adaptable to stage bleeding.

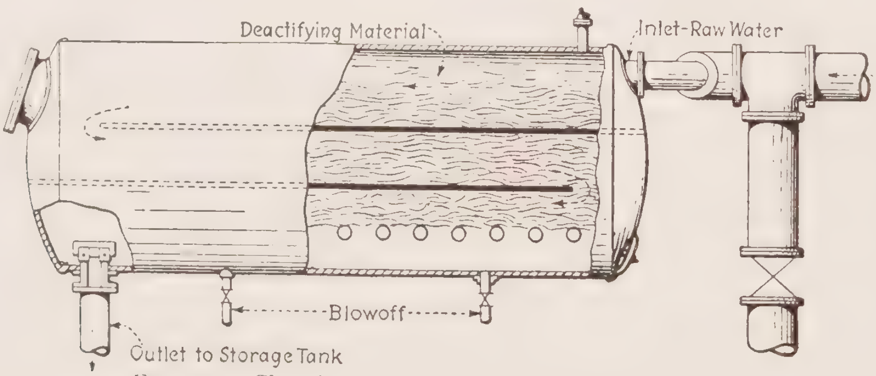


FIG. 17. Chemical Type of Feed Water Deaerator.

Deaeration of Feed Water

It has been known for a long time that certain gases dissolved in water accelerate its corrosive properties, and that when the gases are removed the corrosive tendencies of the water are retarded to a great extent. The problem of minimizing corrosion in boilers and appurtenances has focused attention upon gas removal as a form of feed-water treatment.

Feed-water heating has been practiced widely in the past, and where this has been done in open heaters the gas has been partly removed. The percentage of dissolved gases remaining in water after heating to 212 deg. F. may, however, be sufficiently great in many cases to cause active corrosion of boiler and economizer. Practically complete removal of dissolved gases from feed water is essential in order to stop corrosion. Within the last few years, a number of appliances for degasification have been designed and put into practical operation. Many of these appliances eliminate practically all dissolved gases.

The amount of air taken into solution in water is influenced by other constituents dissolved in the water at the time the solution of the gas takes place. For instance, distilled water will absorb more oxygen at a given temperature and pressure than a water such as may be obtained from a natural source. Likewise, a hard water will absorb less of this gas than a softer water. Sea water will be saturated with a smaller amount of oxygen at a given temperature and pressure than a fresh-water supply under similar conditions.

The area of the exposed surface of the water influences the rate of absorption greatly. Eliminating other influencing factors, the greater the exposed area of water in contact with oxygen, the greater will be the absorption in a given period of time.

The primary object in the deaeration of feed water is the removal of dissolved oxygen, since this gas is the most important single factor in the corrosion of metal by natural waters. Corrosion may be influenced by many conditions, but as a general proposition the corrosive properties of the majority of water supplies become negligible after the water has been freed of dissolved oxygen.

However, waters containing the same amount of dissolved oxygen may not have the same corrosive reaction, since the mechanism of corrosion is a complex phenomenon, subject to many influencing factors. The presence of various constituents in water which deposit to form protective coating on the metal surface will reduce the corrosive action of dissolved oxygen to a marked degree. The temperature of the water, the velocity of the water in contact with the metal and the acidity or alkalinity of the solution, are factors of considerable importance in the rate of corrosion. Disregarding other corrosive factors, however, it is a well established fact that the rate of corrosion of metal by water is proportional to the oxygen content of the water in contact with the metal.

There are two general types of degasification apparatus. These may be designated as (a) mechanical or physical and (b) chemical.

One type of deaerator is based upon the principle of reboiling or scrubbing the feed water by means of live steam. The gases in the water are removed by being forced upward with the rising bubbles of steam. The apparatus consists of a steel shell, in the upper

portion of which are a series of trays as in an ordinary open feed-water heater. The water enters the deaerator at the top and splashes over the trays. The steam enters the equipment at the bottom through perforated pipes or jets and passes upward through the water in the storage space, heating the water falling over the trays above. The gas with some vapor is removed by an ejector, the vapor being condensed and returned to the system. The trays are of the counter-current type and so arranged that the gases and vapor passing to the vent travel between the trays in a direction contrary to that of the water falling from one tray to the next.

Chemical Deaerators

A deaerator which functions by removal of the oxygen by adding oxidizing iron or steel is shown in Fig. 17. This apparatus, termed a deactivator, consists of a steel tank in which are a number of layers of steel laths or perforated sheets over which the water flows.

As indicated in the drawing, the tank is baffled with two horizontal plates to prevent short-circuiting from the inlet to the outlet. The water may be discharged into the apparatus from open or closed feed-water heater and it is employed usually in conjunction with such appliances. When the temperature of the water is lower than 212 deg. F., live steam may be employed to raise the temperature prior to passing through the deaerator. This method of operation is warranted when there is an insufficient amount of exhaust steam and when economizers are not used.

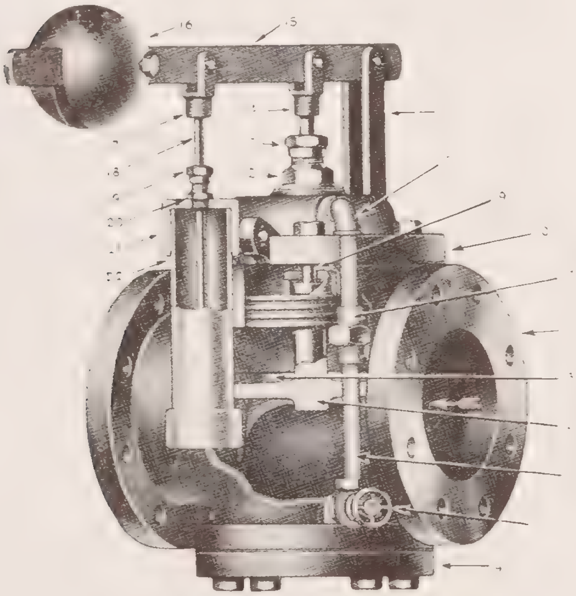


Fig. 18. Back Pressure Valve.

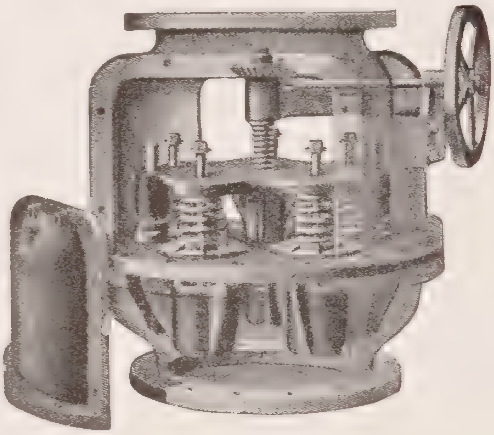


Fig. 19. Multiple Port Back Pressure Valve.

Back Pressure and Atmospheric Relief Valves

In ordinary practice such equipment as radiators, feed water heaters, vacuum condensers, low pressure turbines and absorption ice machines, are not designed to stand up against high steam pressure. The fact remains, however, that the exhaust from engines, pumps or turbines, or steam received through pressure-reducing valves, always presents the possibility of high pressure, unless a satisfactory means of release is provided.

It is obvious that what is required is a safety valve, but it is equally obvious that the great volume and low spouting velocity of low pressure steam demands a valve to handle the exhaust steam, which differs from the safety valve commonly used for high pressure. A valve which would be ample to prevent a rise in pressure above 150 pounds per square inch will be practically useless for discharging steam at five pounds gauge pressure. An opening three inches in diameter will release 1,200 pounds per minute of 150 pounds steam. To release the same amount of steam at five pounds gauge would require an opening 19 inches in diameter.

Back pressure valves are designed to relieve any excess pressure that may build up in the exhaust line of non-condensing engines. They are known as atmospheric relief valves when used where the engines or turbines are running condensing. The two valves are practically identical except for minor details.

The atmospheric valve is usually equipped with a ball and lever set to counter-balance the weight of the valve so that it may open at only slightly over atmospheric pressure, while the back pressure valve has a ball and lever holding the valve down, which can be adjusted to maintain any back pressure required.

It is customary to have the atmospheric valve sealed by water, in order that no air may leak through it and affect the vacuum being maintained.

Fig. 18 shows view of a single valve type of back pressure valve, and Fig. 19 is a section through to multiple port type.

Automatic Temperature Regulators

During the process of manufacturing of certain products it is essential that the temperature be constant at all times and this is very difficult to do by hand.

A few of these processes which demand a constant temperature include drying room, ovens, kilns, and brine cooled cold storage. Also the temperature must be kept constant in cooking kettles, evaporators and other process appliances.

The temperature regulator valve inserted in the steam or brine line will automatically open or close in accordance with the heat which is required to keep the room always at the same temperature.

Fig. 20 is a sectional view of the Sarco regulator, which consists of a thermostat tube 1, a flexible connecting tube 2, a valve moving plunger 3, and a valve 4. Thermostat, connecting tubing, and plunger cylinder 5, are filled completely with a special hydrocarbon oil.

When the large volume of oil in tube 1 expands on being heated, a pressure is exerted on plunger 3, thus tending to close the valve. As the temperature falls, the oil in the thermostat again contracts, allowing the valve to open, assisted by the spring 6.

Since the expansion of the oil is uniform per degree of temperature rise, at any point of the range (0-300° F.), valve action does not depend upon boiling points or critical temperatures, but is even and gradual, so that truly throttling control results, equally accurate at high as at low temperatures.

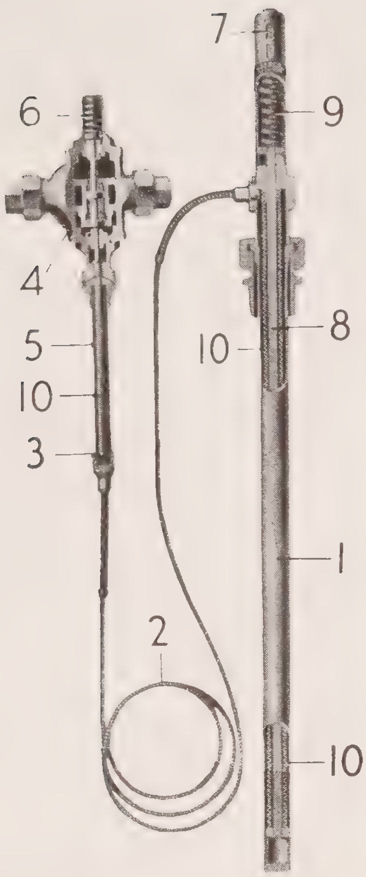


Fig. 20. Sarco Temperature Regulator.

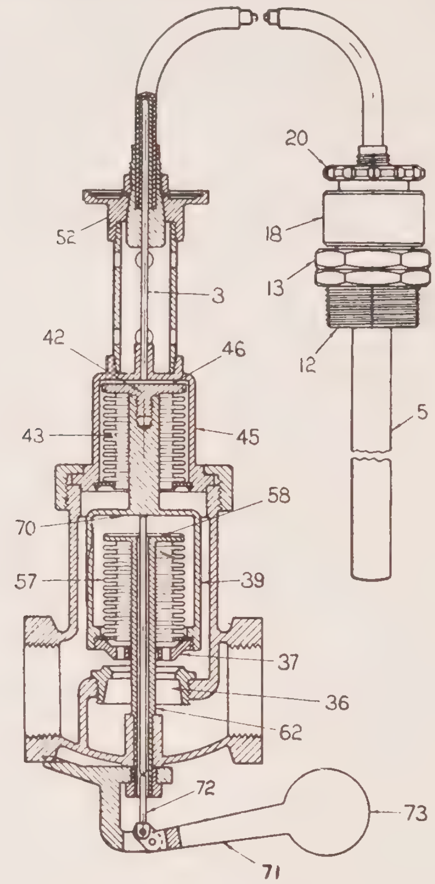


Fig. 21. Another Type of Temperature Regulator.

All Sarco thermostats are equipped with relief springs 9, which take up excess expansion of the oil after the valve is closed. Accidental overheating of the thermostat up to 90° F. above the set temperature will not damage it.

All regulating valves are of the balanced type, double seated for steam and piston type for liquids.

Fig. 21 illustrates another type of temperature regulator in which most of the throttle energy is obtained from the heat energy of the steam in the valve body, less than one per cent. being taken from the thermostatic bulb. The valve disk is numbered 37, the seat ring 36, and central guide pin 62. Balancing includes two flexible metal bellows numbered 43 and 57, each with effective area equal to or larger than opening in 36.

With valve opened or closed, pressure inside valve body against movable wall 42 is always balanced by pressure against effective area of wall 70 or on casing 39, inside of which is exposed to atmosphere through hole in guide stem 62. The valve disk is perforated to allow steam to circulate inside bellows 57 and against stationary wall 58, thus avoiding additional unbalanced area exposed to steam pressure when valve is open. Bellows 43 and casing 45 form vapourizing chamber connected to thermostat through capillary tubing 3. Thermostatic bulb 5 and capillary tubing are normally filled with suitable liquid while a partial vacuum exists in chamber 46. Slight variation in temperature of thermostatic bulb 5 moves

liquid from the relatively cool part of one side of flange 52 to vapourizing temperature inside 46, where it flashes into vapour and expands more than 500 times to close the valve.

Pressure Reducing Valves

Conditions sometimes exist in steam plants where it is found necessary to reduce the boiler pressure of the steam before being used. For instance, the auxiliaries of the main power unit may not be designed to operate on as high a pressure as the unit itself, making it necessary to reduce the pressure before it reached them. Also, some heating plants operate with high boiler pressures which must be reduced before reaching the coils. The apparatus used for reducing the pressure is known as the pressure reducing valve. There are several types of this valve in general use. Fig. 22 shows a ball and lever type manufactured by Darling Brothers.

The operation of the valve is as follows:

Steam enters the high pressure chamber, passing through the valve seats to the outlet side at reduced pressure. About fifteen feet away from the valve on the low pressure side a half-inch pipe is taken off and connected with the underside of the diaphragm chamber, this is the control pipe, and its object in being off the reduced pressure pipe at some distance

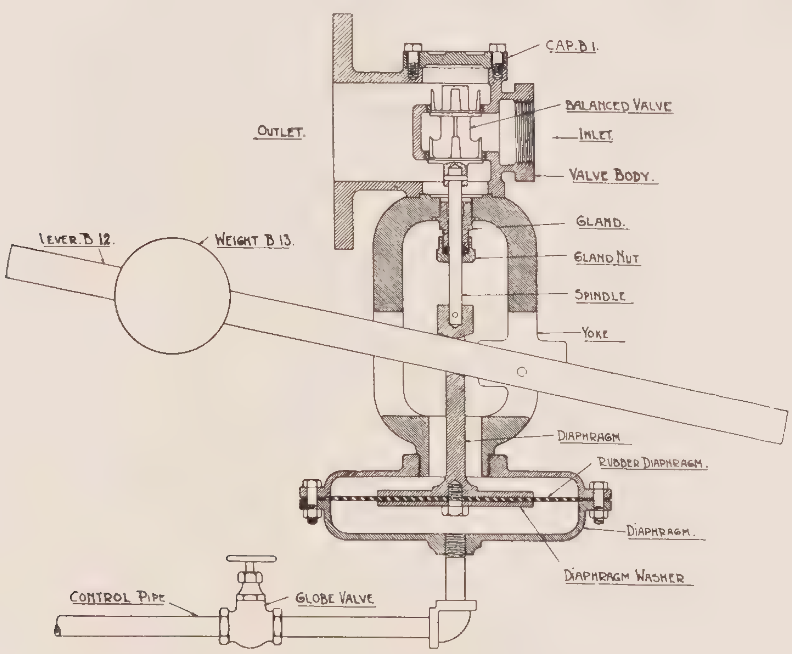


FIG. 22. Pressure Reducing Valve.

from the valve is to obtain an average pressure. The point at which the control pipe enters the diaphragm chamber must be below the point at which it is taken off the low pressure main so as to ensure the rubber diaphragm being protected by a water seal. A globe valve must be placed in this control line, which should be kept shut when using the by-passing around the reducing valve, while repairs are being made to same. Any inclination towards pulsating can be overcome by throttling down on this valve. The pressure on the diaphragm tends to force the valve upwards and close it, this tendency is counteracted by a sliding

weight on the lever, which is connected to the diaphragm. The area of the diaphragm is made large to ensure a sensitive regulator which will respond instantly to the slightly fluctuation in the pressure.

Steam must flow in the direction indicated by the arrow cast on the body. The inner valve can be seen through the inlet end; it is essential that this point be observed, otherwise the regulator will not work.

The regulator must be placed in a horizontal position, with the diaphragm down, so that the water of condensation which forms in the diaphragm chamber will protect the diaphragm from the heat of the steam. Before placing the regulator in position, blow out the pipe and make sure that it is entirely free of scale and dirt. After the regulator has been installed, turn on the steam, making sure that the weight on the lever is as close to the fulcrum as it will go. When the valve is warmed up, slide the weight along the lever until the desired pressure is attained. The farther out the weight is placed on the lever, the greater will be the delivery pressure, and vice versa, the closer the weight to the fulcrum, the less the pressure. If the regulator will not operate, it will indicate that some foreign substance is in the valve, or that the diaphragm requires to be renewed.

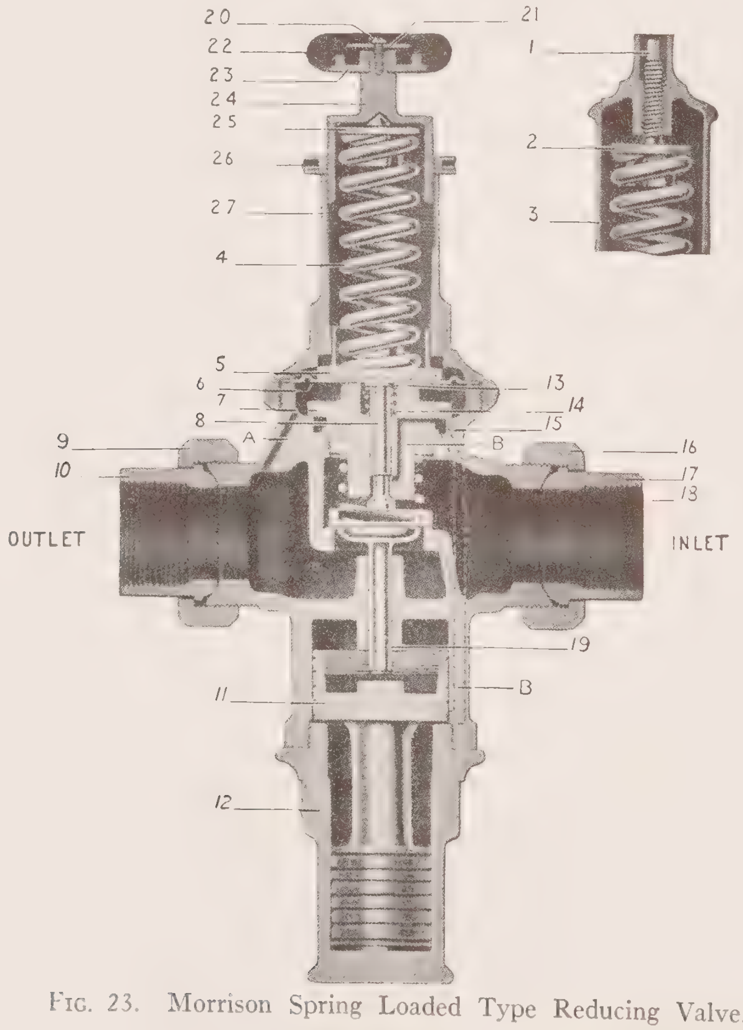


Fig. 23. Morrison Spring Loaded Type Reducing Valve.

Fig. 23 shows a spring loaded Morrison type. These reducing valves are controlled by the variation of the reduced pressure acting through the port A, (shown in the cross section) on the diaphragm, 6. This diaphragm is resisted by the spring 4, which is adjusted to the desired pressure. This construction allows the diaphragm to be raised by an increase of the reduced pressure and forced down by the spring 4, when the reduced pressure is decreased. In use the diaphragm is balanced between these two forces, the slightest change of reduced pressure causing a movement of the diaphragm.

The auxiliary valve 8, is held in contact with the diaphragm by the auxiliary valve spring 14, and moves up and down with the diaphragm. As soon as valve 8, is open steam passes through into port B and under piston 11. By raising piston 11, main valve 19, opens against the initial pressure, because the area of valve 19 is only one-half of the area of piston 11, steam is thus admitted to the system. When the pressure on the low pressure side reaches the required point which is determined by the spring 4, the diaphragm is forced upward by the low pressure steam which passes up through port A, to the under side of the diaphragm 6, allowing valve 8, to close, shutting off steam from piston 11. Main valve 19 is now forced to its seat by the initial pressure, shutting off steam from the system and pushing piston 11, down to the bottom of its stroke. Steam beneath piston 11 exhausts freely around the piston (which is fitted loosely for this purpose) and passes off into the low pressure side.

In practice the main valve does not open or close entirely with each slight variation of pressure, but assumes a position which furnishes just sufficient steam to maintain the desired pressure. Piston 11 is fitted with dash pot 12, which prevents chattering or pounding.

These valves can be furnished for ranges of reduced pressure as follows: 1 to 15 lbs., 5 to 50 lbs., 50 to 140 lbs., 140 to 300 lbs.

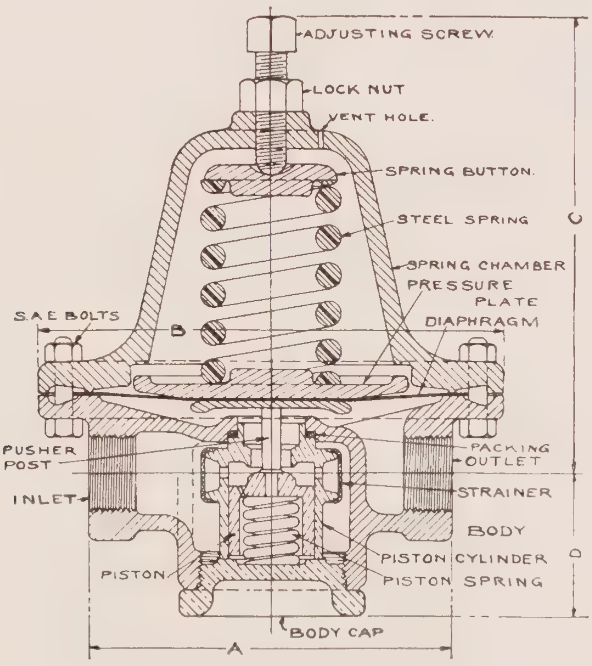


Fig. 24. Cash Reducing Valve.

NOTE: Diaphragm spring 4 is the only one in the valve that needs to be changed to obtain the different ranges of reduced pressures.

The general action of Cash Standard Pressure reducing and regulating valves is basically the same whether the valve is assembled for steam service or for use with any other fluid or gas. Therefore, merely to simplify the description of the fundamental operating principle of Cash Standard regulators, it is assumed that the valve described is operating on a steam line. The action of the single seat class D regulator described typifies the general operation of all Cash regulators. The description can be more readily followed by referring to the sectional illustration, Fig. 24.

Steam at initial pressure entering the regulator on the inlet side passes through the strainer, which precipitates all but the finer particles of foreign substance to the sediment chamber below. It then flows through a series of inlet ports, passes on through the seat opening, through the diaphragm chamber, and through the outlet side into the delivery or working pressure line.

Assume that the initial pressure is 100 lbs. and that the valve is set to deliver 40 lbs. As soon as the delivery pressure exceeds 40 lbs., its action on the under side of the diaphragm

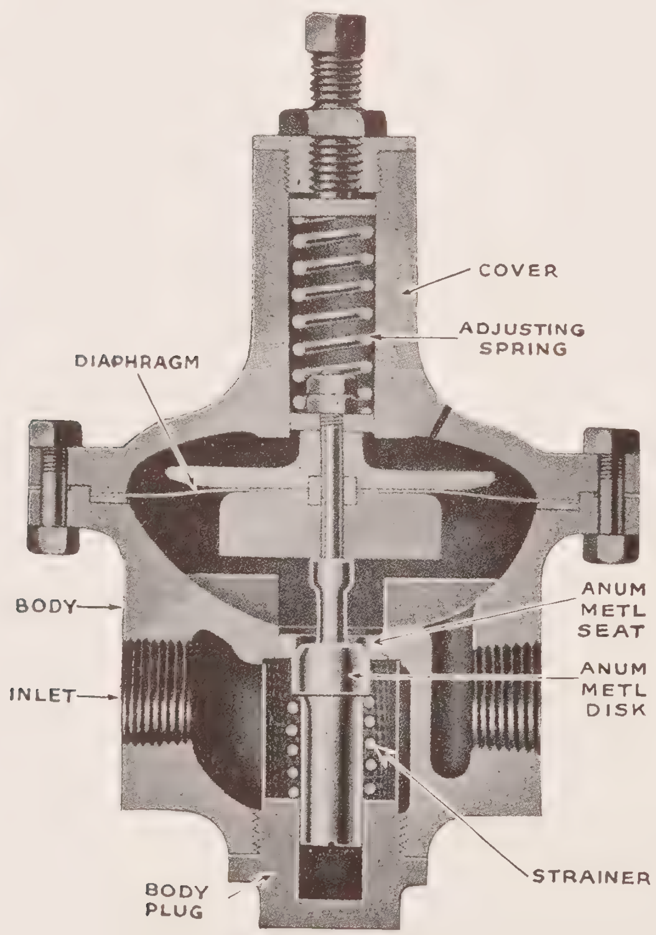


FIG. 25. Strong Reducing Valve.

will raise the diaphragm spring and permit the valve proper to close, or to restrict itself to the point where proper reduction is effected. When the delivery pressure falls, the action of the diaphragm spring will force the valve open to the proper point to restore the required reduction.

Fig. 25 shows a cut of the Strong reducing valve. This valve has a single seat and disc and a self-contained strainer.

The low pressure comes in direct contact with the diaphragm and works against the adjusting spring. If the low pressure increases, the diaphragm is forced against the spring and the valve closes, and if the low pressure decreases, the spring forces the valve open. Screwing down the adjusting nut (see cut) increases the low pressure, and releasing the nut lowers it.

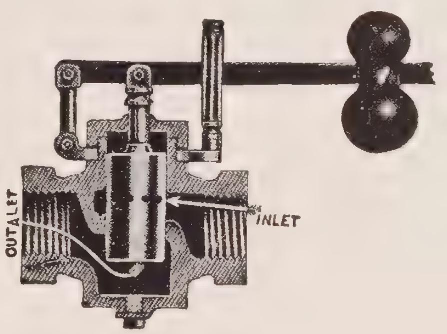


Fig. 26. Lever & Weight Type Reducing Valve.

Reducing Valve With Lever and Weight

Fig. 26 shows a reducing valve with lever and weight. Its operation is as follows. The steam enters the body of the valve and passes through the small holes into the hollow piston and then into the heating system or kettles, when the pressure on low pressure side becomes great enough to overcome the force exerted by the weight and lever, the steam forces the piston up and closes the holes or ports in the piston.

On a heating system or anything requiring a steady pressure the valve will adjust itself to feed in just enough steam to keep up the pressure wanted. As the valve is controlled entirely by the low pressure side, balanced by the lever and weight, variations on the boiler will have no effect upon the pressure on the outlet.

This reducing valve is simple in construction, and metal throughout all parts. It should only be used for lower pressures desired on the outlet up to 25 pounds steam, but for pressures above this the diaphragm reducing valve is better adapted.

Steam Separators

Saturated steam delivered from boilers to pipe line always contains a certain amount of moisture. The percentage of moisture varies greatly, depending upon the design of boiler, also upon the manner in which it is operated, and may vary anywhere from one per cent to twenty per cent, or a rough average of about five per cent.

The amount of moisture present in pipe line is further increased by condensation of the steam, due to faulty insulation.

Moisture has no good qualities and many bad ones. In engines it interferes with proper lubrication, cuts valves and cylinders, absorbs heat by re-evaporating during the expansion of the steam, and if in sufficient quantities, is liable to cause the engine to be wrecked. In steam turbines it cuts the valve nozzles and blades and impedes the velocity of rotor.

Moisture may be eliminated from steam by superheating the steam sufficiently to evaporate all moisture, or, to a certain extent, it may be separated by the use of a steam separator.

The principle of steam separator is that if steam at a high velocity has its direction of travel suddenly changed, the particles of water are by their momentum projected from the steam in a straight line with the direction of original travel, while the steam being of a light nature, is capable of making the turn and separating itself from the water. Any particles of grease, oil or dirt are likewise thrown off by the steam.

From experiments made with different makes of steam separators, it has been proven that moisture of ten per cent or more can be reduced to from two to five per cent.

Fig. 27 shows cross sections of a design of separator, the arrows showing the change in direction of the steam while the water falls to the bottom, from which it should be drained to a steam trap.

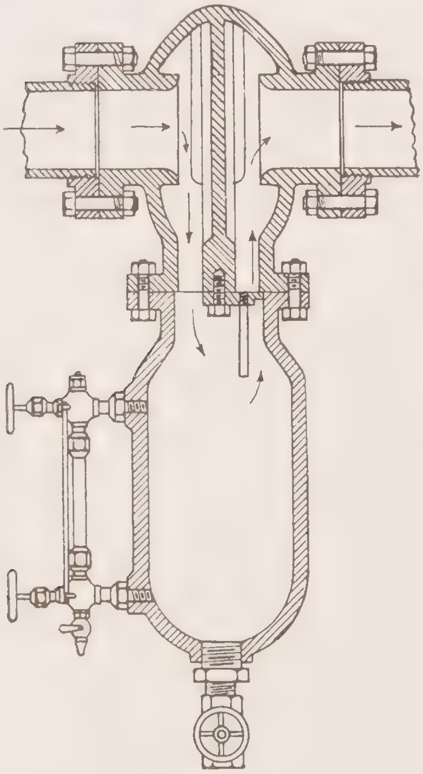


Fig. 27. Steam Separator.

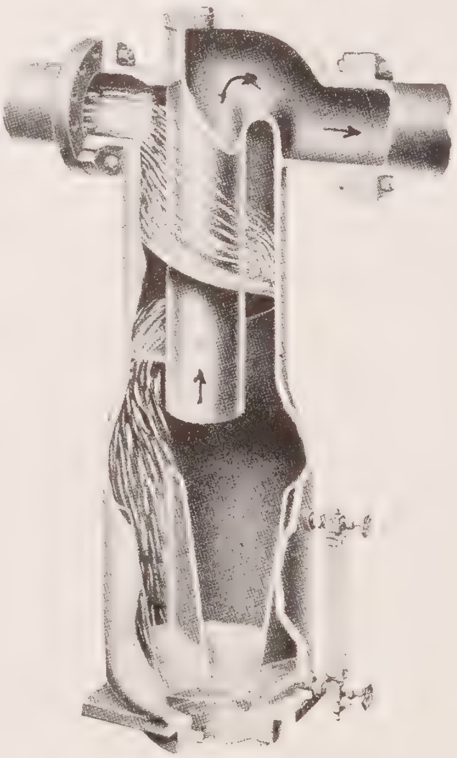


Fig. 28. Steam Separator in which steam is given a swirling motion.

Fig. 28 shows a type in which the steam is made to travel in a helical path. As the steam and water enter the separator, they pass through a helical path formed about a central cylinder. The high velocity of the incoming steam and water causes the entire mass to swirl as it passes from the helical channel into the main body of the separator. Water is several hundred times heavier than the steam, and, therefore, it does not follow the turn so easily, but is thrown out of the whirling current of steam by centrifugal force. The helical path is so proportioned that large or small quantities of water swing out of the curving steam current, meet the wall at an angle without the slightest spatter or splash, and follow close to the wall until the receiver space is reached, at which point the swirling motion of the water is checked by proper baffles, so that drainage may be easily accomplished.

Water-Hammer in Steam-Pipe Lines (Traveller's Insurance Co.)

There is a potential hazard from water-hammer in every steam plant. Although engineers and boiler attendants may know that loud, hammering sounds in steam-pipe lines and serious jarring of the pipes are produced by water-hammer, there may be some who do not understand the precise nature of water-hammer action or realize the possible extent of the danger or know the means and methods by which it may be prevented. A description of the way in which water-hammer action starts, and sometimes progresses to the stage where actual damage occurs, should be interesting; and knowledge of the precautions to be taken to prevent such damage as well as possible loss of life, is essential for safety.

A familiar example of water-hammer action on a small scale is afforded when steam is blown directly into a body of cold water, through a small pipe. Each bubble of steam that leaves the pipe is immediately condensed by the surrounding water so that the interior of the bubble suddenly becomes vacuous. Then (the surface of the water being exposed to an atmospheric pressure of 15 pounds per square inch) the vacuum-filled bubble collapses smartly and suddenly, its sides coming together with a sharp noise and a good deal of force. A similar action occurs when steam is passed up through cold water standing in a partly filled pipe. The condensation of the steam agitates the water and throws it into waves; and if the steam is admitted rapidly, great surges of water soon sweep up and down the pipe, and these, when they strike against a bend in the pipe or against a closed valve, may exert a tremendous force.

When the steam that is admitted does not pass directly up through the water in the pipe, the phenomena that occur are somewhat different at the outset, but in the end they amount to much the same thing. As the steam rushes into the pipe it disturbs the surface of the water, and causes the formation of waves upon it. The turbulence rapidly increases, and in a very short time one of the waves breaks in such a way that its crest, in pitching forward, momentarily forms a bubble-like inclosure, containing steam. By this time there is a certain amount of pressure in the pipe, and as the inclosed steam condenses, the pressure causes the bubble to collapse with more or less noise and force. This greatly increases the agitation of the water in that immediate vicinity, and the same action is rapidly repeated in other places, so that the water in the pipe is soon flying about in the wildest manner imaginable. (This action has been fully studied by direct observation, in glass pipes.) The thing most to be feared is the formation of a surging wave, large enough to block the entire pipe. The

steam that is thereby pocketed on the side away from the steam inlet rapidly condenses, and the incoming steam drives the wave to the end of the pipe, where it strikes with great force; and so the action continues, with large waves coursing up and down the pipe at high speed, and striking smashing blows against the ends.

Pipes are often pulled out of their fittings in this way, and the fittings themselves are often broken; and in accidents of this kind steam at high pressure is frequently liberated in immense quantities, with exceedingly grave consequences.

Precautions to Avoid Water-Hammer

To avoid trouble from water-hammer action, drains should be provided at the lowest points of every pipe line, and the attendant should invariably open these drains and remove the trapped water as completely as possible, before opening the steam valve. It often happens, particularly when there is a vacuum in the steam pipe, that the condensed water will not run out freely—the vacuum drawing air into the pipe instead of allowing the water to escape. When this occurs the drain should be left open, and after a considerable quantity of air has entered through it, the steam valve may be opened by a mere crack, so as to admit a small amount of steam to warm up the air in the pipe. This operation should be performed carefully, and only by a man with excellent judgment. When the confined air has been warmed in this way (so that a slight pressure has been produced) a considerable part of the water will run out, if the drain is free. In order to remove the water thoroughly, it may be necessary to repeat this process two or three times. The attendant should not try to hasten the operation, but should take time enough to assure himself that the pipe is actually free from water before opening the steam valve except in the cautious way, and to the limited extent, that we have already described. He should rely upon the expansion of the air to expel the water, instead of trying to force the water out by direct steam pressure.

In many plants the drains operate automatically, discharging into traps. Additional, hand operated drain pipes should then be provided so that the attendants may assure themselves that the automatic draining has been effectively done.

After a pipe has been thoroughly drained, and the attendant has satisfied himself that no more water is present, the stop-valve through which steam is to be admitted may be cautiously opened, the hand wheel being turned only a slight amount at first. In a few minutes it may be opened a little more, and when the attendant has satisfied himself that it is quite safe to do so, he may gradually turn the hand wheel to the wide-open position. The valve should not be opened full, however, until the pipe has become well warmed up, and it is important to remember that the act of turning steam into the cold pipe is attended by condensation, so that water will accumulate in the pipe to some extent, in consequence of the admission of the steam.

For this reason it is the part of wisdom to close the stop-valve after it has been partly opened for a time, and to drain off the water that has condensed during the warming up process. In large pipes, or pipes that are unusually cold, it is advisable to repeat this operation two or three times, and the attendant should be ready, at every moment, to close the

stop-valve immediately, if any pounding or other disturbance occurs. The presence of air in the pipe tends to diminish the force of the blow somewhat, in case water-hammer action occurs, because the air acts as a cushion.

In a plant where two or more boilers are set in a battery and are connected to a common main steam pipe or header, water-hammer action of a specially severe type may occur when one of the boilers that has been shut down for a time, is fired up and the connection between it and the main steam line is re-established.

This operation, called "cutting-in," should be entrusted only to an experienced and trustworthy person. It is always attended by considerable danger unless it is performed with great care; and although the danger can be reduced by providing automatic stop-and-check (or non-return) valves on the branch pipes that connect the several boilers to the main steam pipe, it can never be reduced, either in this way or in any other way, to such a point that it will cease to call for careful consideration and cautious and intelligent management.

Pump Governors

Should a reciprocating boiler feed pump be used, an excessive water pressure will build up in the feed line, if the boiler feed valves are closed tight and the pump continues working. It is usual to install an instrument to automatically slow down or stop the pump when the feed valve is closed. This is known as a pump governor.

There are a large number of designs of pump governors on the market. One of the simpler makes is shown in Fig. 29. The governor is installed in the steam line leading to the steam cylinder of the pump, in such a way that the steam flows through the double seated balance valve C, entering at A. The force of the spring holds the valve open, thus

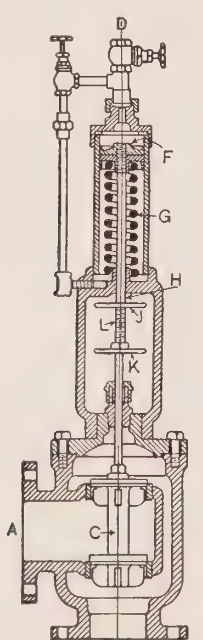


Fig. 29. Pump Governor.

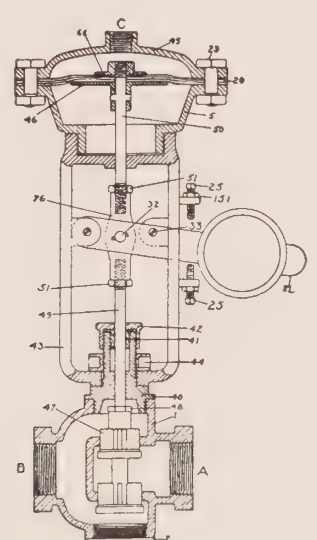


Fig. 29-A. Governor used on pumps where vacuum heating system is installed.

allowing the steam to pass out at B. A small pipe is connected from the discharge water line of the pump and to the top of the governor at D, thus allowing at all times the full water pressure downward on the top of the piston F, in opposition to the spring which presses upward on the piston.

As the pressure on the piston increases it finally overcomes the force of the spring G and pushes down the valve, thus shutting off the supply of steam to pump. When the discharge pressure decreases, the force of the spring overcomes the pressure on the piston and opens the valve. In some designs the piston is replaced by a diaphragm similar to that shown in Fig. 29A.

Practically the same governor can be used for controlling the speed of engines driving blower fans, except that provision must be made so that the valve cannot close tight and stop the engine, but rather allow enough steam to reach the engine to keep it turning over.

In the case of fan control, a steam pipe connects the boiler to the piston chamber of the regulator; thus the pressure in the boiler controls the speed of the fan engine.

In case of a vacuum heating system where a steam pump is used, a governor, shown in Fig. 29A, can be used to control the desired vacuum on the heating system. It will be noted that in this case instead of having a pressure tending to force the valve closed there is a vacuum tending to hold it open, therefore, the spring which tended to force the valve upward is replaced by a weight and lever tending to force the valve downward. The valve is equipped with adjusting screws (25) to govern the speed of the pump.

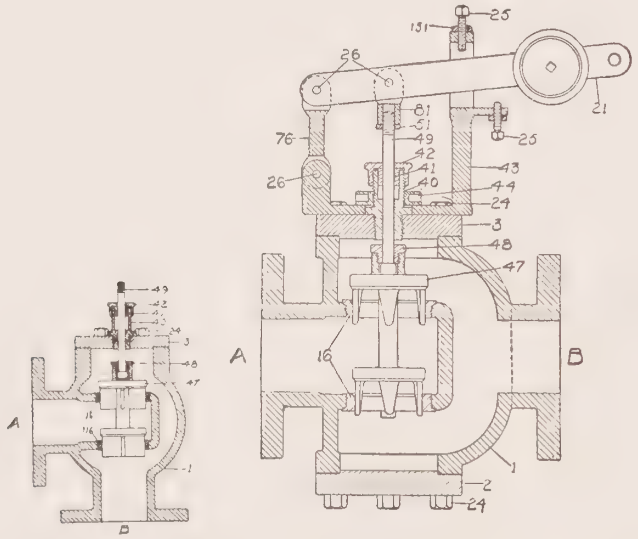


FIG. 30. Balanced Valve. (This contains the double seated balanced valve No. 16, thus requiring very little pressure to open and close. Used with advantage where quick opening valves are necessary).

Ejectors

Figure 31 is a sectional view of a single stage, single divergent nozzle ejector. Some ejectors which are designed for ejecting air from condensers where high vacuum is essential consist of two or more nozzles arranged in such a manner that the first nozzle discharges into the second.

Ejectors are frequently used on the steam condenser, or on any vessel from which air is required to be drawn, in place of, or as auxiliaries to the air pump. They are also quite often used to drain flooded cellars or as auxiliaries to sump pumps.

The action is as follows. Steam, water or air under pressure enters at A and passes through the nozzle, entering at C and leaving D, at a high velocity, thus creating a partial vacuum. Air, gas, water or whatever is to be exhausted, is drawn into the instrument by the vacuum and is carried along and discharged into the atmosphere at E.

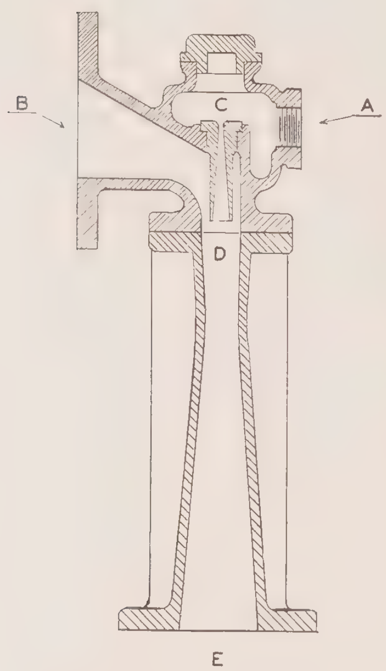


Fig. 31. The Ejector.

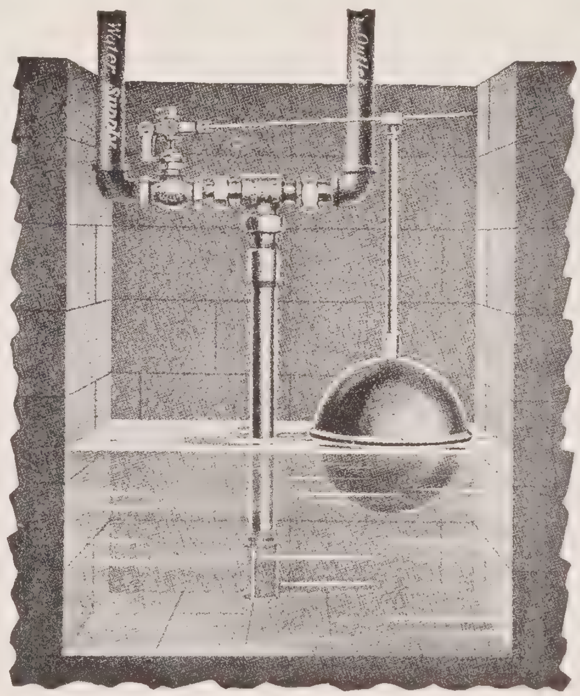


Fig. 31-A. The Ejector applied.

Siphon

If a bent tube is filled with water, and placed in a vessel of water and then ends unstopped, the water will flow freely from the tube, so long as there is a difference in level in the water in the two vessels. A bent tube of this kind, used to transfer a liquid from one vessel to another at a lower level, is called a siphon.

To understand the cause of the flow consider Figure 32.

The pressure at A tending to move the water in the siphon in the direction AC
= the atmospheric pressure—the pressure due to the weight of the water in AC;
and the pressure at B tending to move the water in the siphon in the direction of BD
= the atmospheric pressure—the pressure due to the weight of the water in BD.
But since the atmospheric pressure is the same in both cases, and the pressure due to the weight of the water in AC is less than that due to the weight of the water in BD, the

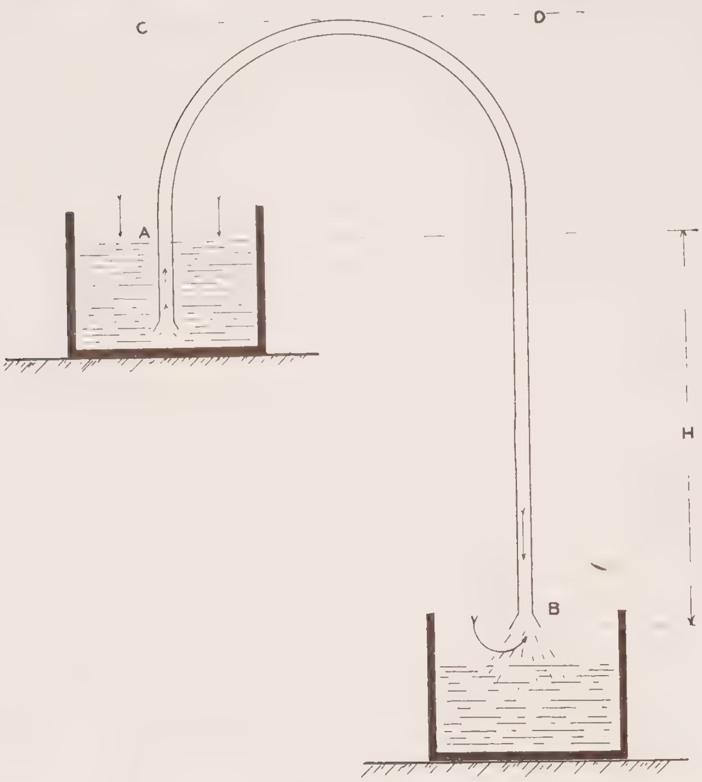


FIG. 32. Siphon.

force tending to move the water in the direction AC is greater than the force tending to move it in the direction BD; consequently a flow takes place in the direction of ACDB. This will continue until the vessel from which the water flows is empty or until the water comes to the same level in each vessel.

If the tube is perfectly air tight, the distance from C to A may be about thirty-three feet and the siphon will still work, but if it is more than thirty-four feet, it cannot work because the atmospheric pressure will only support a column of water of thirty-four feet.

Siphons are often used on a large scale in engineering. For instance, in power plants the water used to condense the steam in the condenser is often taken from a body of water, raised 10 or 15 feet to the condenser, and carried back to the body of water, through a pipe that is everywhere air-tight and acts like a siphon. The only work that the pumps have to do is to keep the water moving against the friction in the pipe. Siphons are also used in aqueducts to carry water over hills. In such cases air bubbles carried along in the water tend to collect at the top of each hill, and so small air pumps have to be installed to keep the pipes full of water. In chemical laboratories glass siphons are much used in drawing liquids from stock reagent bottles.

Automatic Stop Valve

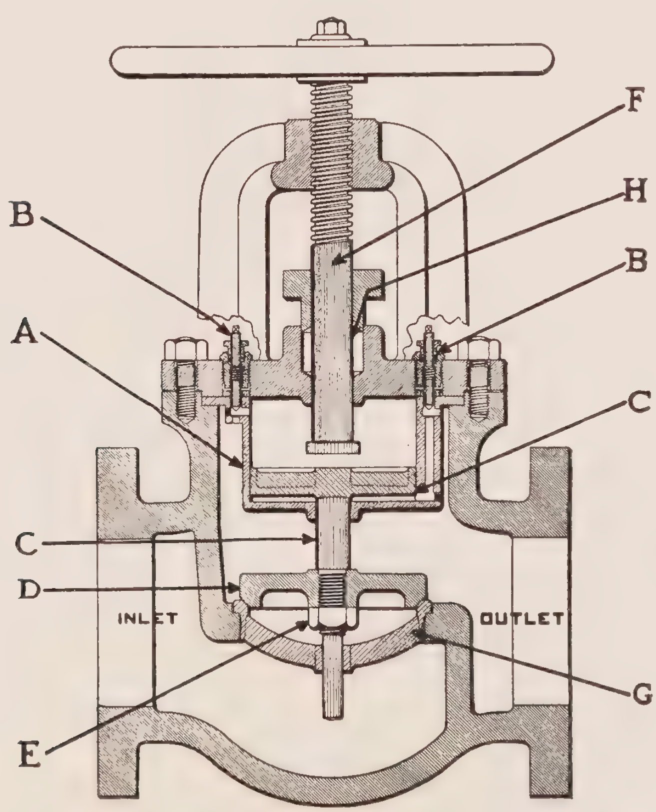
Where a plant consists of two or more boilers connected to a common header, each boiler should be equipped with an automatic non-return valve. This valve is for the purpose

of automatically cutting in and cutting out a boiler. It is constructed on the principle of a check valve, and opens if the pressure is greater in the boiler than in the steam line but closes if the pressure in the steam line is greater. A dead boiler equipped with this valve is protected from steam backing into it from other boilers, or, if due to some accident, such as the rupture of a tube, the injured boiler is automatically shut off from the other boilers.

Figure 33 shows a cross section of a non-return valve. It will be noted that this valve is equipped with a valve stem and wheel, but, unlike other valves, the stem is not connected to the valve disk. The valve may be closed by hand and held closed but it cannot be opened unless steam pressure is exerted upon the bottom of the disk. To bring a boiler in on the line the valve stem may be turned to the open position but the valve seat will remain closed until pressure in the boiler becomes slightly greater than in the line, when the valve disk will automatically open and cut in boiler. The valve is equipped with a dash pot to allow the valve to work smoothly and prevent pounding and chattering.

Stop valves should not be placed in vertical steam line unless it is possible to drain the condensate that collects above the valve when the valve is closed.

A gate or globe valve should be placed on the steam line between the stop valve and



STOP AND CHECK VALVE

A—Large Internal Dash Pot.
B—Cushioning Port Valves.
C—Piston Stem Integral with Piston.
D—Cast Iron Disc.
E—Disc Jam Nut.
F—Main Valve Stem.
G—Bronze Seat Ring with Disc Guide.
H—Large Packing Space.

Fig. 33. Stop and Check Valve.

the header in order that steam may be shut off for repairs and examination. Like all other automatic machinery, it should be examined frequently and kept in good repair.

Care should be taken while opening the valve by hand, that the disk is following the stem. If the disk for some reason should remain on its seat while the valve stem is backed away, it may suddenly release and open wide, causing a tremendous surge of steam into the line with disastrous results. The operator can tell if the valve is following the stem by the "feel" of it.

Design and Layout of Piping (Extract from "Power", Feb. 1935)

If a piping designer were concerned only with the primary purpose of piping—transportation of a fluid from here to there—his job would be easy. But he must consider many other factors, and these become at times both difficult and important. Too often, for example, ease of operation and appearance are overlooked in the effort to design the least costly piping system consistent with safety, reliability and operating flexibility.

The starting point in the design of any system of piping, whether for main or auxiliary steam lines, heating systems, boiler feed, condensate or service water, should be a line diagram showing all equipment to be connected and all valves required. Right here, operating flexibility must be considered and balanced against its cost. One must here decide whether to provide a double or loop header arranged so that maintenance can be carried out without interfering with general plant operation, or a single-header system arranged so that any small repair means a major shutdown.

Between these extremes is a middle course which yields an economical, yet sufficiently flexible and reliable, system. The tendency is toward greater simplicity and a corresponding willingness to face the possibility of a partial shutdown in case valve or pipe maintenance becomes necessary. This perhaps is an outgrowth of the better and more reliable valves, pipe, joints and fittings now available.

In the making up of these diagrams don't overlook future plant additions; arrange the piping for easy extension to serve new equipment.

The next job is to determine the pipe sizes and weight of pipe. For all ordinary service conditions the dimensions of flanges, fittings, and pipe have been standardized. American standards exist for 125-pound and 250-pound cast-iron fittings, and tentative American standards for steel fittings and A.S.T.M. specifications 106-33T for seamless steel pipe for 250-, 400-, 600-, 900- and 1,500-pound steam pressures at 750 deg. F. In general, these standards are fully equal to the operating conditions for which they are rated. Thus, selection of pipe, flange and fitting dimensions is merely a simple choice of the proper standard.

Consider, however, the nature of service. For example, a pipeline carrying high-temperature steam that is to be cut in and out of service at frequent intervals, should be of heavier pipe than would normally be selected. This is particularly true for small-sized pipe where screwed connections are used. In any sizeable job where different pressures and fluids are involved, it is worthwhile to make up a schedule of pipe, flange and fitting dimensions used in different service.

Pipe size must, of course, be based on the volume of the fluid to be carried. The size must be such as will result in reasonable velocities and pressure drops of the fluid flowing. The following table gives velocities which experience indicates are reasonable for various services.

Steam	Velocity, Ft. per min.
Boiler leads	6,000 to 12,000
Headers	6,000 to 8,000
Branch lines	6,000 to 15,000
Exhaust lines	6,000 to 15,000
Saturated steam for heating	4,000 to 6,000
Water	
Boiler feed	480 to 600
General Service	300 to 600
City	120 to 300

It is possible in many cases to determine the pipe size by economic analysis. For example, consider the case of piping to supply steam to a turbine. The smaller the pipe installed the less its first cost and yearly carrying charge. But the smaller the pipe the greater the pressure drop, which increases the turbine steam rate and hence the cost of fuel per kw. hr. With given cost of fuel and load factor, a pipe size can be found which will result in the lowest total fixed charges on cost of pipe and insulation, and cost of fuel for supplying steam to the turbine. In some instances limited allowable pressure drop will determine pipe size.

With these preliminaries completed, the designer is ready to lay out the system to meet the physical requirements of the plant. Drawings and specifications that he makes should be complete and leave nothing to the imagination. There are usually a great variety of ways the piping can be run, but the designer must remember that his work will be judged by the reliability, appearance and ease of operation of the installation. Ease of operation is often neglected and, as a result, the operator finds it necessary to set up a stepladder or crawl over a maze of piping to operate certain valves. All valves should be as accessible as possible; those operated regularly should be within easy reach, or remote control provided. Valves used regularly require repair, and space for maintenance should be allowed when location is chosen. Arrangements of by-passes should be such that the purpose of each valve is evident at a glance.

Much can be done in the early design of a power plant to help in securing neat and well-appearing piping by providing pipe galleries and by considering piping when locating turbines, pumps, heaters, etc. Assembly drawings are almost a necessity to good appearance and in large installations a model of the plant including the main piping repays its cost by eliminating many mistakes. In general, elbows look better than bends, and pipe run out at 45 deg. should be avoided. Piping should run parallel or perpendicular to the axis of the plant and should be kept in a single plane as far as practicable. Where clearances are close, the designer should remember to provide room for flanges and insulation. Of course welded piping takes up less space.

Provide For Expansion

All power piping is subject to temperature changes. While this is particularly true of steam piping it is true also of service-water piping where temperature changes of 60 deg. may be encountered between winter and summer conditions. Temperature changes cause changes in the length of pipe. Unless provision is made to accommodate them, severe and dangerous stresses and thrusts may damage the pipe or connected equipment.

It is easy to figure the change in length of a run of pipe with temperature change, which should be taken as the maximum possible. When the average coefficient of expansion of the pipe material is known, change in length may be found from the formula.

$D = 12\ CL\ (t_2 - t_1)$ where D is increase in length in inches, L length of pipe line in feet at temperature t_1, t_1 and t_2 initial and final temperatures and C average coefficient of expansion.

Metal	Average Coefficient	Temperature Range
Cast Iron	0.00000653	0 to 300
Steel	0.00000756	0 to 500
Wrought Iron	0.00000716	0 to 300
Brass	0.0000101	0 to 250

There are two ways in general use for taking care of expansion: 1—expansion joints; 2—flexibility of the piping system obtained either by expansion loops and bends or change in direction. When space is limited, creased and corrugated bends may provide a solution. The analyses necessary to determine the expansion a piping system may safely stand due to its own inherent flexibility are too complex to explain in these articles and should be entrusted only to a specialist in this field. Methods of analysis have been quite completely treated in the "Piping Hand Book" and a practical graphical method is given in "A Manual for the Design of Piping for Flexibility by the Use of Graphs". Designed pipe flexibility is used to absorb expansion in all high-pressure piping systems.

Combinations of welding elbows and straight length of pipe are also being advocated for expansion.

For lower pressures (up to 250 to 350 lb.) expansion joints are in general use. These are of two types: slip type and packless joints of corrugated metal or rubber. When expansion joints are used, pipelines should be well supported and guided so that no binding in the joint will occur as the pipe expands and contracts. Slip-type joints usually permit more movement than the packless joint, but packless joints can be installed in less space.

Before expansion stresses can be calculated, it is necessary to decide upon points of fixed and sliding anchorage and the means of pipe support. Fixed anchorages are usually made at important junction joints and are designed to fix the pipe vertically, transversely and longitudinally.

In general, it has been more convenient to support power-plant piping on hangers or on brackets from building columns. Piping run in tunnels, however, is usually supported

from below. In either case the supports must be arranged to permit movement of the pipe. Hangers should always be arranged to allow vertical adjustment. Each support should be strong enough to hold its share of the pipe and insulation when filled with water. With solid hangers a safety factor of 10 should be used, because pipe expansion sometimes lifts it clear of one or more hangers, thus concentrating the weight. With spring hangers, the safety factor can be cut to 5, as these types compensate for pipe movement. Certain special patent hangers are designed to permit the line to move up and down while they exert a constant supporting lift. With ordinary spring hangers the supporting lift of the hanger decreases as the pipe moves vertically and the springs close.

Supports should be spaced and adjusted so that drainage is assured and pipe deflections will not form pockets.

Sway bracing should be used to prevent pipe vibration and to keep the lines in place. These are particularly necessary on boiler feed lines where violent vibrations often result from surges caused by sticking control valves, air bound pumps and other causes of water hammer.

Pipe-Line Drainage

All piping, whether for water, air, saturated or super-heated steam, should be arranged for drainage. In water piping drains should be provided for each section of the system, so that the line may be emptied of water when repairs are necessary. In the case of steam lines, however, drains and trap connections must be provided to keep the line free from condensate whenever it is in operation. Drainage piping should not be less than ¾ in. Steam piping should be arranged so that pockets are avoided as much as possible. When they are necessary they should be well drained. Lines should be installed with a uniform grade of 1 in. in 20 ft. so they will drain to a definite point. Better drainage is obtained if the lines are sloped in the direction of steam flow. Particular care should be taken in locating valves to see that condensate will not accumulate on top of the valve when closed; if such location cannot be avoided ample drain facilities must be provided. Neglect of this point will cause trouble, particularly in the case of valves in boiler leads and turbine or engine stop valves.

Although little condensate collects when superheated steam is flowing, such lines should, nevertheless, be provided with drains, as considerable condensate will collect when superheated steam lines are shut down. This must be removed before the line can be put in service again. Open blows are essential in warming up steam lines to insure expulsion of air and condensate.

Whenever a steam line approaches a turbine or engine from above it is good practice to provide a drip pocket with drain connection at the bottom. In fact the bottoms of all vertical risers should be trapped. Successful operation of steam and oil separators depends largely upon the reliability of the drain facilities provided. Drip and trap piping operates under more severe service conditions than the main piping and for this reason is often made of heavier standard than the main piping.

An essential factor in the economical installation and successful operation of a piping system is the valves selected, and any discussion of piping without considering valves would

be incomplete. However, in the limited space of this article only general suggestions pertaining to valve selection can be given. Globe valves are used in those places where throttling is a service requirement. Globe valves are seldom used in water lines because of pressure drop through them. Gate valves are used where pressure drop is a consideration and in locations where the valve will be either wide open or completely closed. Control valves (Globe) should be preceded by gate valves located usually near the header so that the line can be shut tightly for repair to the control valve. When a valve is subject to severe cutting a guard valve, usually a gate, should be provided for tightness such as is done for boiler blow-off connections.

Check valves should be installed at the discharge of all pumps that deliver to a common header to automatically prevent back flow when the pump is shut down. They should not be counted upon to be tight, and a gate should be used with them. Check valves should be used at the feedwater inlet to the boiler, with gate valves on either side, and in drip lines that discharge to a common header or receiver.

Small valves, as used for instrument piping, drip connections, etc., are usually globe valves. It is good practice to install a valve close to the point where instrument piping connects to the main piping, and an open blow connection, with valves on both sides of it, at the instrument. This arrangement permits blowing out the line without danger of injury to the instrument. It also provides a place for checking accuracy of the instrument.

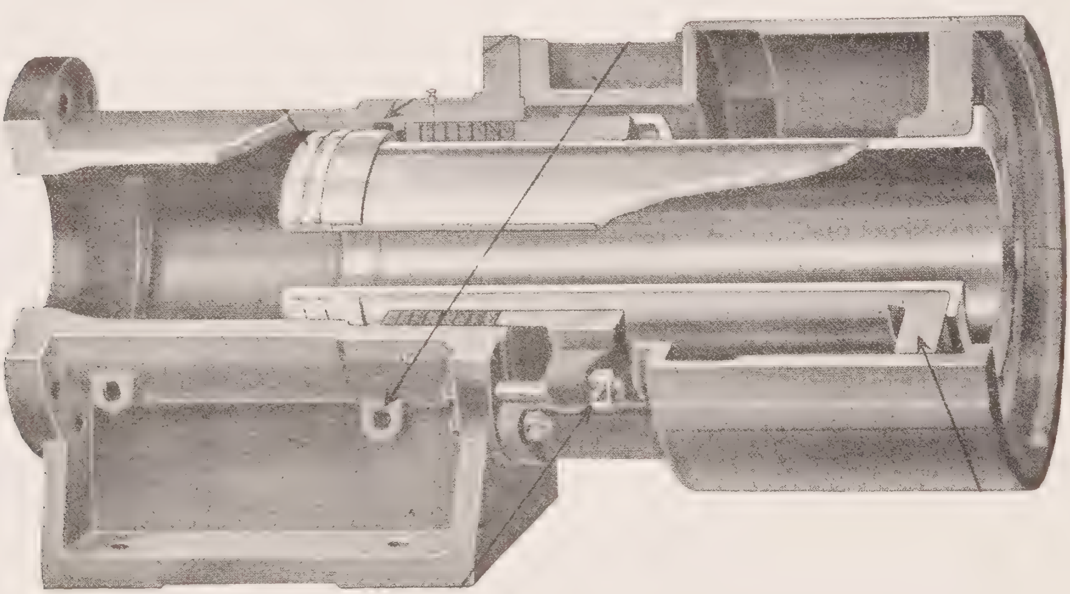


Fig. 34. Slip Joint. (Used to take care of expansion in long pipe lines.)

Expansion and Contraction of Piping

The expansion and contraction of piping because of temperature changes is large enough to demand careful consideration. Higher pressures and higher degrees of superheat emphasize the importance of the subject, as does also the increasing use of efficient insulating materials.

The amount a pipe will expand depends upon its initial length, the rise in temperature to which it is subjected and the coefficient of linear expansion of the material.

The coefficients of expansion of a substance, is that part of its original length which a body will expand for each degree of change in temperature.

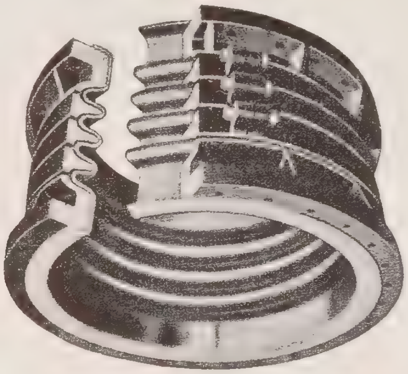


FIG. 35. Corrugated Copper Expansion Joint.

COEFFICIENTS OF LINEAR EXPANSION OF PIPING MATERIALS

Material	Temperature Range	Mean Coefficient C. per deg. F.
Wrought Iron and Mild Steel	32-212	0.00000656
Wrought Iron	32-572	0.00000895
Cast Iron	32-212	0.00000618
Cast Steel	32-212	0.00000600
Hardened Steel	32-212	0.00000689
Nickel-Steel, 36% nickel	32-572	0.00000030
Copper, cast	32-212	0.00000955
Copper, wrought	32-572	0.00001092
Cast Brass	32-212	0.00001043
Brass Wire and Sheets	32-212	0.00001075

Steam piping, when heated from ordinary atmospheric temperature to the temperature of steam at 150 pounds pressure, will increase in length approximately ¼ inch for every 10 feet in length.

Example: In a greenhouse at Brampton they have 600 feet of straight run of wrought iron pipe carrying steam at 150 pounds pressure. In the erection of this pipe, what allowance should have been made for expansion?

We will assume the temperature of the atmosphere when the pipe was erected, was 50 degrees.

The temperature of steam at 150 pounds pressure is 366 degrees.

The pipe will, therefore, be subjected to a change in temperature of $366 - 50 = 316$ degrees.

From the table we learn that:

1	foot of pipe with			1 deg.	rise in	temperature	expands		.00000895 ft.
600	feet "	"	"	1 "	"	"	"	"	.00000895 × 600 ft.
600	" "	"	"	316 "	"	"	"	"	.00000895 × 600 × 316 = 1.69692 feet = 20 inches.

Pipe Anchors

The expansion of piping cannot be limited, but its direction can be pre-determined by anchoring one end, both ends or the middle of a run. If one end is anchored, the expansion must be absorbed at the free end of the line. If both ends are anchored, the expansion will be from them toward the middle of the run and must be absorbed, preferably at some one place. With centre anchorage the expansion is forced toward the free ends of the line, where it must be absorbed.

Anchors must be firmly fastened to a rigid and heavy part of the power-plant structure, and must also be securely fastened to the pipe. If the pipe is not prevented from moving at

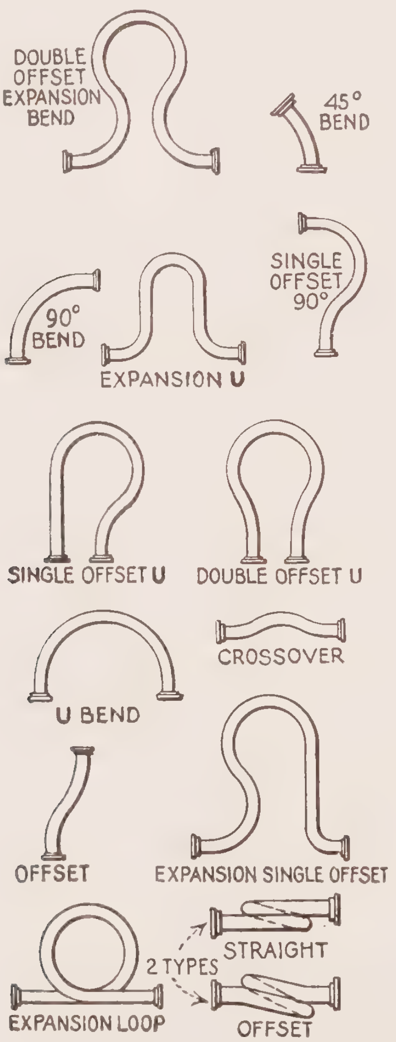


Fig. 36. Common Pipe Bends.

the point at which the anchor is applied, the entire equipment for absorbing expansion is useless and severe stresses will be thrown on all parts of the piping system. When both ends of a straight run are anchored with an expansion joint between, the end thrust is the steam pressure multiplied by the cross-sectional area of the pipe at its largest diameter. With slip joints like Fig. 34 the area is that of the outside diameter of the sleeve; and with corrugated joints as Fig. 35, or their equivalent, the largest inside diameter of the corrugations is to be taken. Thus, a 12-inch pipe with a slip-joint carrying steam at 250 lbs., will develop an end thrust of nearly 17 tons, and it may be greater than this with a corrugated joint.

Expansion Joints

Pipe bends (see Figure 36) offer a satisfactory means of providing for expansion. The pipe should be straight on each end for a distance equal to twice its diameter. Pipe bends should be fitted with extra heavy lapped of welded flanges, because the joints are subjected to severe stresses. Expansion is absorbed by a bend only because it is sprung out of normal shape, thus permitting the line to expand.

Expansion joints are of two general types. Slip joints consist of a brass sleeve, sliding in a stuffing box. They are made with and without anchor bases, and with traverses up to about ten inches. In the second type, expansion is cared for by the axial spring of a corrugated copper pipe. For high pressures, the copper is re-enforced by inner and outer iron equalizing rings. Both types are useful when lack of space prevents the use of pipe bends.

The piping between the anchors should be carefully lined up so that there will be no tendency for it to spring or buckle if the slip joint is too tightly packed. Bolts are necessary to prevent the sleeve being drawn out by such circumstances as the failure of an anchor.

Supports and Hangers

Pipe supports and hangers vary of necessity with the plant layouts, but their construction is fairly well standardized. Pipe supports, Figures 37 and 38 can be divided roughly into three classes—hangers, standards and brackets. Hangers are used for supporting piping from ceilings and overhead structural members; standards for supporting piping on and from engine and boiler-room floors; and brackets for supporting piping on and from walls and vertical structural members.

The plainer and lighter types of pipe hanger can be used for short runs, with steam or water lines up to about six inches diameter. On long runs they can be used if the connection between the hanger ring and the ceiling is long, and if its upper end is not rigidly attached to the ceiling.

For large pipe, long runs, or when the supporting strap must be short or rigid, the hanger should be equipped with one or more rollers. The support for high temperature lines should be equipped with a lower roller and also with a roller resting on the top of the pipe. The upper roller should be bolted by tie-rods to the support. Springs should be placed between the support and rods, so that the latter can move slightly. Supports for large or heavy mains should be adjustable to maintain alignment.

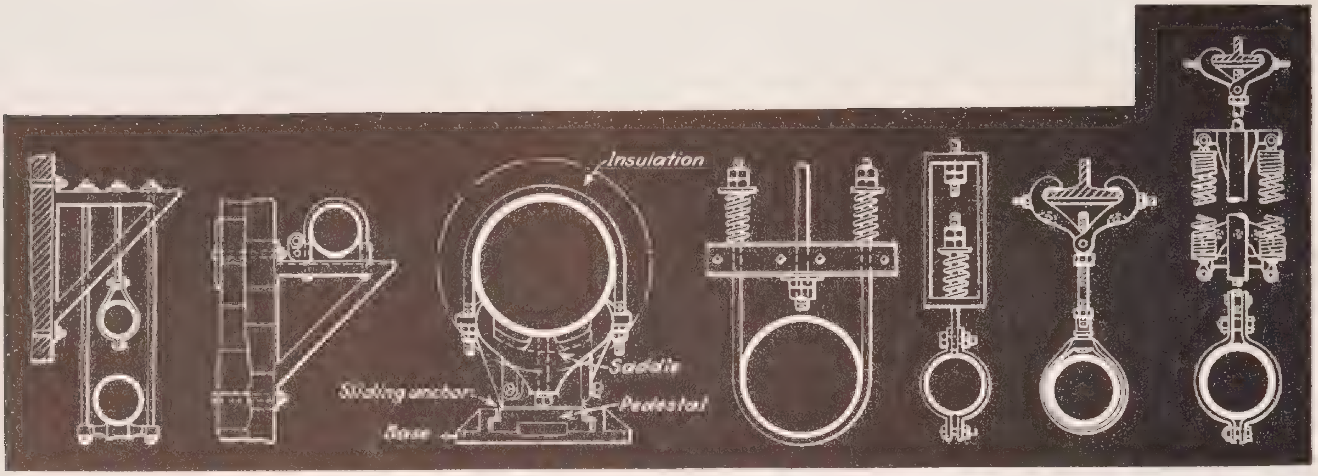


FIG. 37. Pipe Supports.

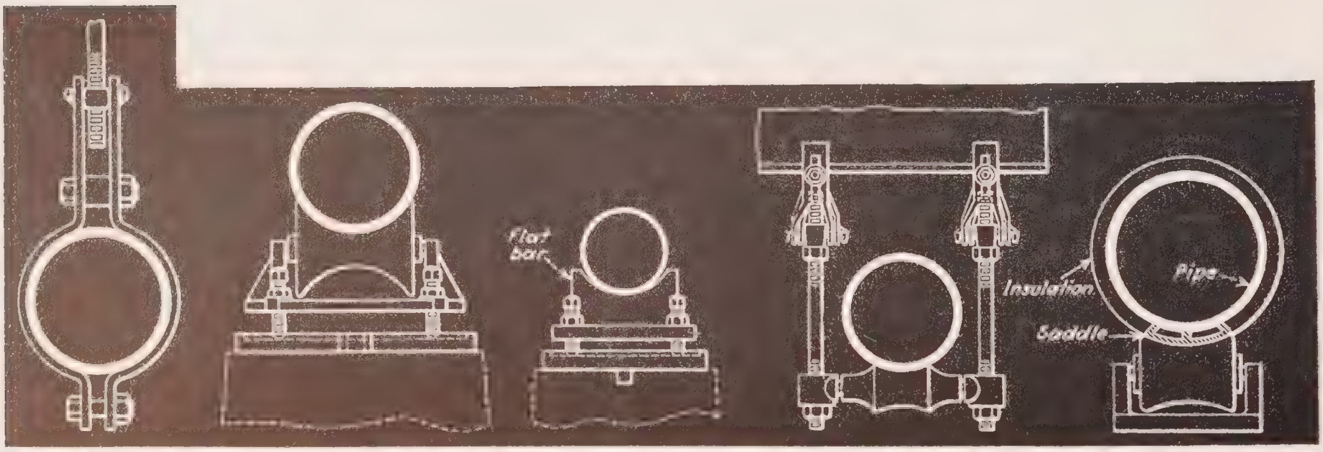


FIG. 38. Pipe Supports.

Maintenance of Pipe Line

Corrosion is the maintenance man's worst enemy. Anything he can do to prevent it—tighter joints, system redesign, changed materials or operation—redounds to his own advantage. Dissolved oxygen comes first as a cause of power piping corrosion, particularly in hot feedwater lines. The remedy is to keep oxygen out of the system or take it out with deaerating heaters. Feed heaters should be amply vented and vacuum-type heating systems kept tight against air infiltration. Men should be cautioned against hunting for H.T. steam leaks by passing hands over joints. H.T. steam is invisible and burns very seriously almost instantaneously.

Most important is frequent routine inspection, which, with orderly scheduled maintenance, will avoid emergency repairs. Units requiring regular repacking, inspection or

cleaning should be provided with bypasses or be in duplicate as should vital valves and auxiliaries. Steam, feed and service water lines which must be kept in service at all costs should likewise be in duplicate. If traps on the dead side of a duplicate system fail to operate (if the system is kept alive or valves leak) pipes will fill with water and cause leaky joints. Traps should be installed with shut-off valves or bypasses.

No maintenance man can work successfully without proper tools and supplies. This means that he must have lengths of pipe of the sizes, types and materials he must replace, plus an ample assortment of fittings, valves and gaskets. Packings for joints and valve stems, reseating tools, a supply of good lumber for scaffolding and supports (instead of the usual reused and dangerous odd bits) annealed chain and several sizes of rope should supplement the usual pipe-fitter's tools, as well as equipment for detecting leaks in refrigerant lines and determining stresses in flange bolts on high-temperature lines.

Proper system design, correct hanger spacing and enough expansion joints will avoid vibration. Expansion joints are a vital element in maintenance. Sometimes there is trouble with an expansion bend which does not fit accurately, meaning a change in the bend. Sleeve-type expansion joints require regular lubrication and repacking. Pipe hangers, spring hangers and anchors must be inspected regularly to avoid shifting and bad stresses or failure, and one man should be trained for their particular repair. New pipe, before installation, must be cleared of dirt and dirt pockets must be cleaned out of old pipe periodically, particularly in heating systems.

Pipe Joints

Pipe designers have supplied so many types of joints, each with its particular virtues, that the power engineer is in a quandary. On page 46 are 25 common joints for power service and process piping, each with its virtues, each with its faults.

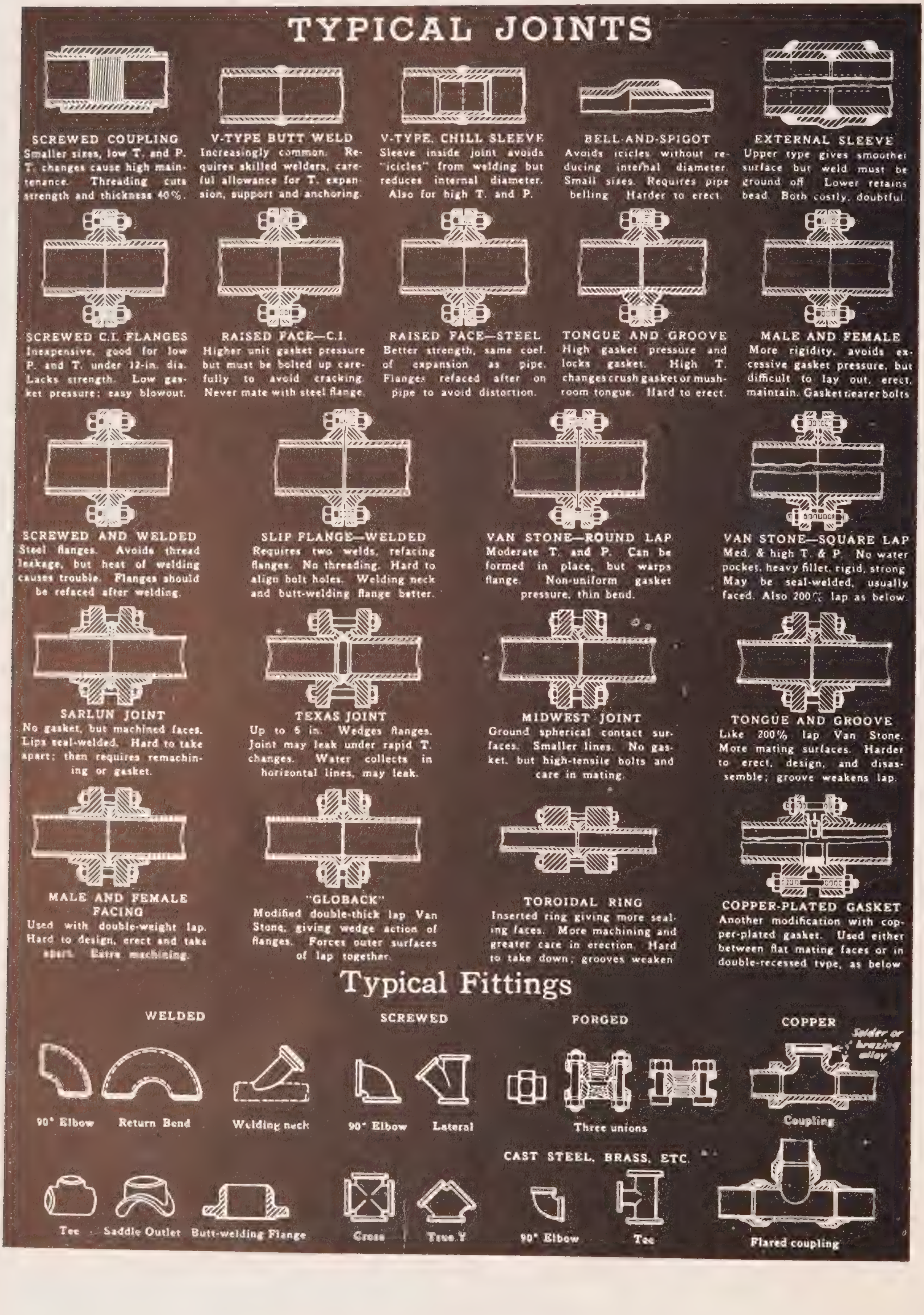
While the primary purpose of any pipe joint is to withstand internal pressure, it must also withstand possible stresses due to bending, expansion and contraction, line load, over-rigidity of the system, unequal initial tension in flange bolts, poor machining (far too often, facing the backs of Van Stone laps is neglected, giving poor flange alignment), unparallel flange faces—even poor basic design. Any of these are likely to impose stresses far above those created by internal pressure. In screwed joints, factors of safety must provide liberally for corrosion.

Major piping systems, particularly those for high temperatures or pressures, should be designed by specialists.

On page 46 are a few typical fittings for each important assembling method. In this connection, it should be mentioned that a number of special patented fittings are available for use with non-ferrous materials or stainless steels for ordinary service.

Insulation

This article can only touch the high spots, for lack of space. Detailed information and dependable application specifications are given in the catalogues of established manufacturers.


TYPICAL JOINTS
SCREWED COUPLING
Smaller sizes, low T. and P. T. changes cause high maintenance. Threading cuts strength and thickness 40%.
V-TYPE BUTT WELD
Increasingly common. Requires skilled welders, careful allowance for T. expansion, support and anchoring.
V-TYPE, CHILL SLEEVE
Sleeve inside joint avoids "icicles" from welding but reduces internal diameter. Also for high T. and P.
BELL-AND-SPIGOT
Avoids icicles without reducing internal diameter. Small sizes. Requires pipe belling. Harder to erect.
EXTERNAL SLEEVE
Upper type gives smoother surface but weld must be ground off. Lower retains bead. Both costly, doubtful.
SCREWED C.I. FLANGES
Inexpensive, good for low P. and T. under 12-in. dia. Lacks strength. Low gasket pressure; easy blowout.
RAISED FACE—C.I.
Higher unit gasket pressure but must be bolted up carefully to avoid cracking. Never mate with steel flange.
RAISED FACE—STEEL
Better strength, same coef. of expansion as pipe. Flanges refaced after on pipe to avoid distortion.
TONGUE AND GROOVE
High gasket pressure and locks gasket. High T. changes crush gasket or mushroom tongue. Hard to erect.
MALE AND FEMALE
More rigidity, avoids excessive gasket pressure, but difficult to lay out, erect, maintain. Gasket nearer bolts
SCREWED AND WELDED
Steel flanges. Avoids thread leakage, but heat of welding causes trouble. Flanges should be refaced after welding.
SLIP FLANGE—WELDED
Requires two welds, refacing flanges. No threading. Hard to align bolt holes. Welding neck and butt-welding flange better.
VAN STONE—ROUND LAP
Moderate T. and P. Can be formed in place, but warps flange. Non-uniform gasket pressure, thin bend.
VAN STONE—SQUARE LAP
Med. & high T. & P. No water pocket, heavy fillet, rigid, strong. May be seal-welded, usually faced. Also 200% lap as below.
SARLUN JOINT
No gasket, but machined faces. Lips seal-welded. Hard to take apart; then requires remachining or gasket.
TEXAS JOINT
Up to 6 in. Wedges flanges. Joint may leak under rapid T. changes. Water collects in horizontal lines, may leak.
MIDWEST JOINT
Ground spherical contact surfaces. Smaller lines. No gasket, but high-tensile bolts and care in mating.
TONGUE AND GROOVE
Like 200% lap Van Stone. More mating surfaces. Harder to erect, design, and disassemble; groove weakens lap.
MALE AND FEMALE FACING
Used with double-weight lap. Hard to design, erect and take apart. Extra machining.
"GLOBACK"
Modified double-thick lap Van Stone, giving wedge action of flanges. Forces outer surfaces of lap together.
TOROIDAL RING
Inserted ring giving more sealing faces. More machining and greater care in erection. Hard to take down; grooves weaken
COPPER-PLATED GASKET
Another modification with copper-plated gasket. Used either between flat mating faces or in double-recessed type, as below
Typical Fittings
WELDED
90° Elbow
Return Bend
Welding neck
Tee
Saddle Outlet
Butt-welding Flange
SCREWED
90° Elbow
Lateral
Cross
True Y
FORGED
Three unions
CAST STEEL, BRASS, ETC.
90° Elbow
Tee
COPPER
Solder or brazing alloy
Coupling
Flared coupling

Pipe covering serves first as a barrier or dam to the flow of heat. At the same time it must not deteriorate at the temperature of the pipe. Other requirements for a good pipe covering for hot or cold lines are: practically air-tight application (absolutely air-tight in case of cold lines); sustained strength; ability to resist occasional wetting; ease of application; ease of removal and re-application without damage; good appearance.

For the insulation of hot water and steam lines in industry, there is little place for the cheap "air-cell" types of asbestos insulation used on domestic jobs. Suitable insulations for these jobs include "85% magnesia", felted asbestos, various types of mineral wool. Perhaps most widely used in this service is molded 85% magnesia—a non-proprietary product of several manufacturers.

Molded insulation for small pipes comes in three-foot sections cut in half and covered with light-weight pasted canvas. For a first class power job the halves are bound in place with loops of 16-gauge annealed iron wire, covered with resin-sized sheathing paper, then with eight-ounce canvas sewn in place with linen thread. The canvas is then glue-sized and painted with two or more coats of oil paint.

The "standard" thickness covering referred to in table is primarily an 85% magnesia standard. It is about 1 in. for pipes less than 4 in.; 1⅛ in. for 4-in. pipe, 1¼ in. for 8-in., 1½ in. for 12-in., and up. "Double standard" consists of two standard-thick layers. These are applied one over the other, with all joints staggered. The inner layers, without canvas, is separately wired.

Very large pipes (as well as drums of heaters, boilers, etc.) are lagged with moulded blocks, machined to fit curvature, wired in place, covered either with hard finished cement or with sheathing paper and sewed 8-oz. canvas. Large fitting, flanges, etc., are often covered with casings built up of insulating blocks and cement, wire reinforced. They may be made removable. Small fittings are insulated either with cement or with premolded covers. Pipe bends are insulated with short pieces of blocks or sectional covering, wired on, filled with insulating cement and covered with hard-finish.

Ordinary asbestos and magnesia insulations begin to disintegrate at 550 or 600 deg. For higher steam temperatures use an inner layer of high-temperature molded insulation (see table) or use a straight mineral-wool insulation adapted to high temperature.

The good insulating qualities cheaply obtainable with felted hair or wool can be utilized in the case of pipes carrying somewhat warm or somewhat cool water, the former not hot enough to destroy the organic matter, the latter where the principal object is to prevent sweating in humid weather.

In the case of refrigerating piping, good insulating value and right thickness are no more important than air-tight application. Entering air will deposit frost and eventually ruin the insulation. Application requires skilled use of seal-compound layers between layers of insulation. This is distinctly a branch for specialists; they should always be called in on any important job.

APPROXIMATELY RECOMMENDED THICKNESSES FOR INSULATION

	Temperature of Pipe Surface—deg. F.								
	—20 to —10	—10 to 5	5 to 25	25 to 50	50 to 70	70 to 300	300 to 450	450 to 600	600 to 700
Pipe Size	Standard Hair Felt					85% Magnesia			H.T. Mag.	
Under 2 in.	4	3	3	2	1	St'd	1½	2	2	-----
2 to 3½ in.	4	4	3	2	1	St'd	1½	2	1½	1½
4 to 6 in.	5	4	3	2	1	St'd	2	D.S.	1½	1½
7 in. and over	5	4	3	2	1	St'd	2	D.S.	1½	2

St'd = Standard Thickness.
D.S. = Double Standard Thickness.
H.T. = Inner Layer of special molded high-temperature insulation.

BOILER FEED-WATER TREATMENT

Impure Water

The feed water for the boilers must not injure the metal of which the boilers are built; it must be as free as possible from air, carbonic acid, salts of ammonia, decomposed foods, chlorides, etc., and it must not produce scale by the deposit of sulphates of lime, carbonate lime, magnesia, alumina and iron, which not only reduce the efficiency of the boilers, but likewise, if neglected, render them dangerous. In addition to this, impurities cause considerable expense in the way of delay, cleaning and repairs, and the loss due to the necessity of blowing down at more frequent intervals than would be necessary had better water been supplied. In fact, this blowing down of the boilers is one of the serious heat losses of the

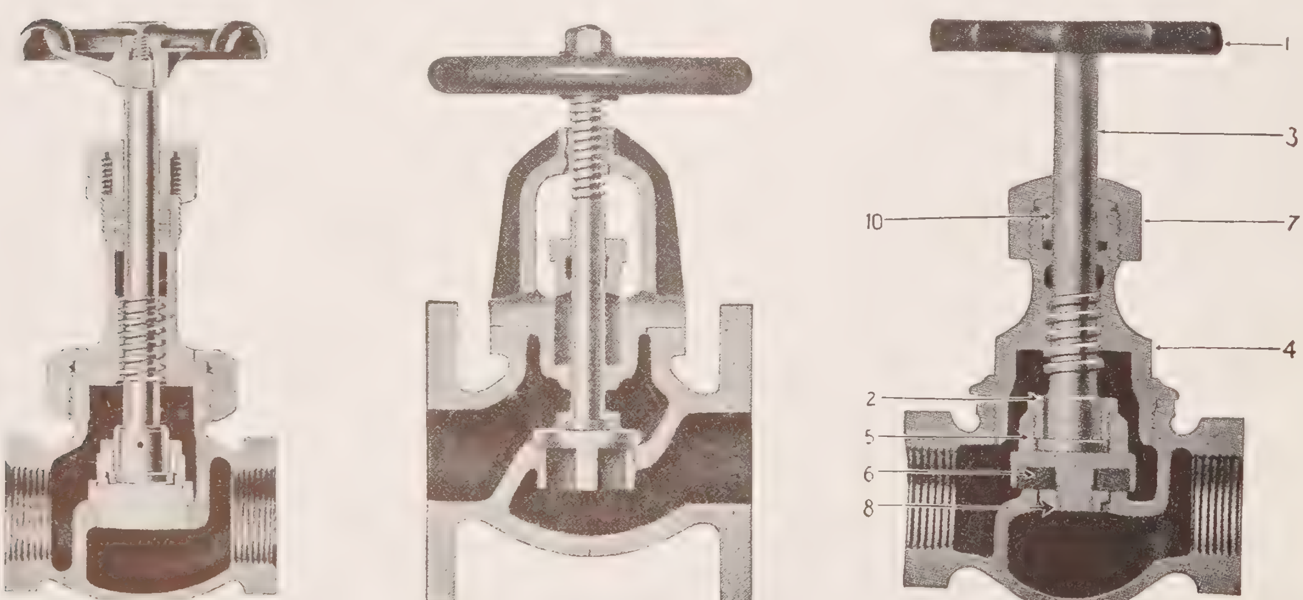


Fig. 39 Three Types of Globe Valves.

FIG. 40. Three Types of Gate Valves.

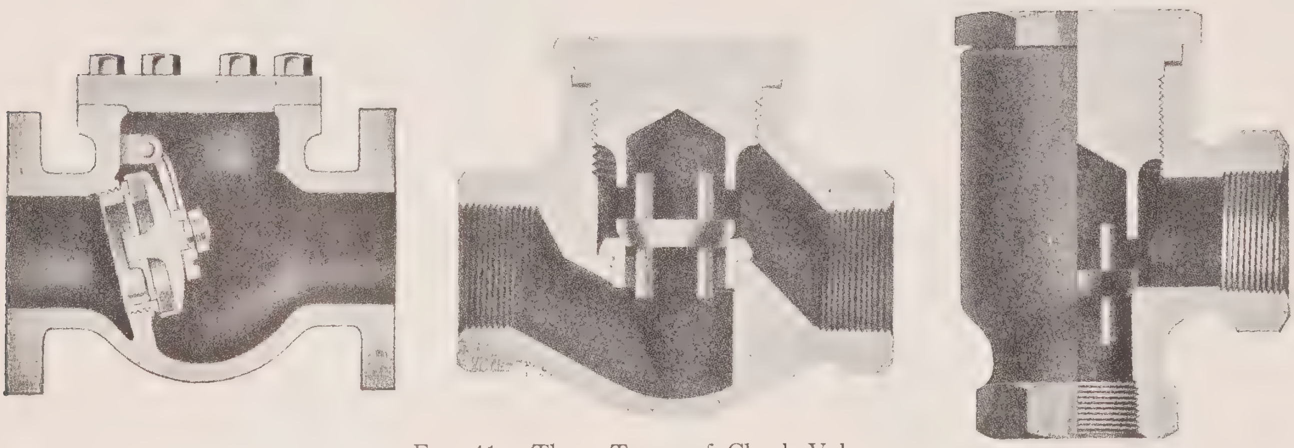


FIG. 41. Three Types of Check Valves.

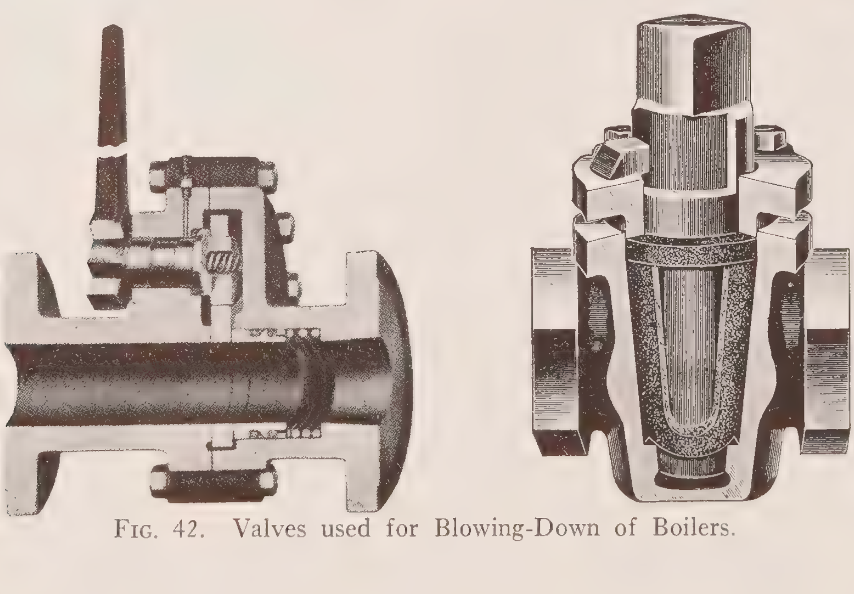


FIG. 42. Valves used for Blowing-Down of Boilers.

plant, while the amount of energy wasted in this matter is too frequently not recognized by power plant operators.

The amount of solids deposited in a boiler is often astonishing; over 300 pounds per month may be deposited in a 100-horsepower boiler, using water which shows only seven grains of solids per U.S. gallon, and in some localities a boiler can only be operated two or three days between cleanings. The impurities met with in feed water may produce one or several of the following results:

1. Internal corrosion of boiler;
2. Precipitation of mud, etc.;
3. Formation of scale;
4. Scum, which causes excessive priming and foaming.

Mud

When provision is made to catch the mud and blow it off before it settles on the heating surface, the only evil is the cost of the heat lost. If this mud, however, is carried along and deposited on the heating surface, it may unite with the scale-forming materials present in the water and the mass will be baked on the surface of the plates and tubes, forming a very hard scale, which is costly and difficult to remove.

Boiler Scale

The effect of scale depends largely upon its density. Those formed by carbonates are usually soft and porous and their retarding effect upon heat transmission is small, except when present in large quantities. Sulphates and a few other impurities deposit a hard scale, so hard that they can only be removed by chipping or cutting them loose by some sort of a machine. These scales are impervious to water and are a source of positive danger, because the metal upon which they have been deposited cannot transmit its heat to the water in the boiler, which is liable to burn, crack, or, should the metal reach a red heat, bulges will be formed, or possibly a partial destruction of the boiler will occur.

The following are the most common scale-forming materials:
Calcium (lime) Carbonate, $CaCO_3$; Calcium Sulphate, $CaSO_4$; Magnesium Carbonate, $MgCO_3$; Magnesium Sulphate, $MgSO_4$.

Magnesium and calcium carbonate are but slightly soluble in water and are usually combined with carbon dioxide, forming bicarbonates of calcium and magnesia ($CaH_2(CO_3)_2$ and $MgH_2\ (CO_3)_2$), which are quite soluble in cold water. When this water is heated, the carbon dioxide (CO_2) is driven off, decomposing the bicarbonates and precipitating the comparatively insoluble mono-carbonate of lime and magnesium hydrate. This decomposition occurs between the temperatures of 180° to 290° F. The scale formed by carbonate of calcium is comparatively porous and does not adhere strongly to metal, and is, therefore, not troublesome unless present in large quantities. This is also true of magnesium carbonate alone, but this substance follows the water currents and settles very slowly and when other

substances are present it tends to cement them together, forming a more troublesome scale. These substances will often cause violent thumping in the boiler, which may have serious results. The magnesium and calcium sulphates are the most troublesome scale-forming impurities. They are not deposited until about the temperature of 300° Fahrenheit is reached. The magnesium deposits a mono-hydrated salt and its presence is objectionable because it interferes with the removal of other impurities. Calcium sulphate is deposited in long needle-like crystals, which have active cementing properties and when mingling with other matters form a very hard and troublesome scale.

Scum

Sewage and vegetable matter when present in the boiler form a glutinous skin on the surface of the water, which may be so serious as to interfere with the working of the plant. Some of these materials may be due to animal or vegetable compounds used as dilutents to the cylinder oil, which enter the boiler from the hot well and condenser. When soda compounds are used in the boiler or contained in the feed water, these oils may be saponified. In such a case "soapsuds" and violent thumping are the result. A surface blow-off is a good method of handling scum, but such blow-offs are troublesome in operation.

Hard feed water is usually treated by one of the following methods:

1. Lime and Soda treatment.
2. Lime and Zeolite treatment.
3. Boiler compound treatment.

The first two treatments take place outside the boiler and the third inside the boiler.

Lime-Soda Treatment

Generally, in using the lime-soda method, a large tank is filled with water into which is introduced a correct amount of milk of lime and soda. Agitators within the tank stir the mixture thoroughly; afterwards it is allowed to stand for a number of hours, during which chemical action takes place—the sulphate of the calcium and magnesium being replaced by carbonates, and sodium sulphate formed. The mixture is then drawn off and filtered through sand and gravel beds, where the calcium carbonate is collected. The sodium remains in solution in the water but does not interfere with boiler operation.

The material composing the filter bed consists of properly washed and graded gravel and special silica filter sand of the proper effective size and co-efficient of uniformity to meet the requirements of the water to be filtered. The entire depth of the filter bed is about forty inches.

In the bottom of the filter is placed the wash and collecting manifold system, consisting of a central header with lateral pipes every six inches. The laterals are provided with bronze strainers every six inches, which means that for every square foot of filter bed there are four strainers.

Being evenly distributed under the entire bed, the strainers assure an even draft on all parts of the filter bed during the process of filtration and an even distribution of wash water when back washing the filter.

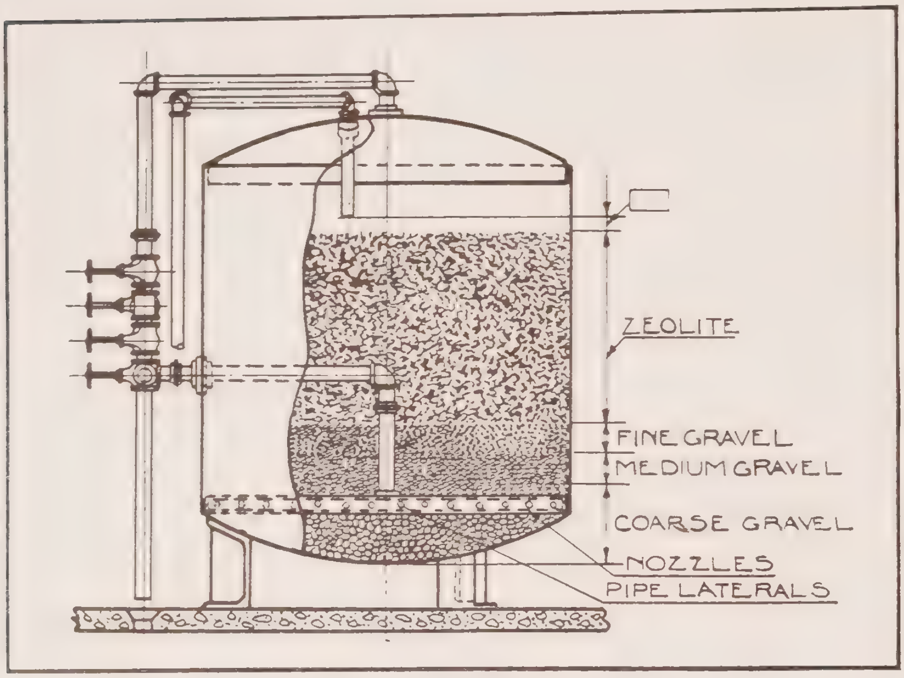


FIG. 43. Permutit Zeolite Water Softener.

The Permutit Zeolite Softener

The Permutit Zeolite softener (Fig. 43) consists essentially of a bed of the mineral suitably supported in an open or closed container. The water to be softened percolates through this bed of mineral, which removes the hardness automatically as the water flows through. When the specified capacity of the softener has been reached as indicated by a meter, it is restored to its original state (regenerated) by passing through it a solution of common salt, which is thereafter run to the sewer. No chemicals are added to the water, and all fluctuations in hardness of the raw water are automatically taken care of without any adjustment whatsoever.

Permutit Zeolite is a hard, insoluble, granular mineral. It possesses the remarkable property of removing all hardness from water by exchanging its sodium base for the hardness forming impurities in the raw water. Since these sodium salts are harmless and do not precipitate at ordinary boiler concentrations, the softened water is ideal for boiler feeding.

Boiler compound is fed directly into the boiler with the feed water.

When regenerated the verdite contains a large amount of sodium, one of the elements of common salt. When hard water is filtered through a bed of verdite a chemical exchange is made between the sodium and the hardness. The hardness is held by the verdite and the water now free from calcium and magnesium in any form, is perfectly softened.

To understand how this exchange is made, consider the following chemical equations in which the various forms of hardness, both temporary and permanent, are shown. The regenerated verdite is represented by the term Na_2 V, that is, Sodium Verdite:

$$
\begin{array}{llllllll}
Ca\,(HCO_3)_2 & + & Na_2V & = & CaV & + & 2NaHCO_3 \\
Mg\,(HCO_3)_2 & + & Na_2V & = & MgV & + & 2NahCO_3 \\
CaSO_4 & + & Na_2V & = & CaV & + & Na_2SO_4 \\
MgSO_4 & + & Na_2V & = & MgV & + & Na_2SO_4 \\
CaCl_2 & + & Na_2V & = & CaV & + & 2NaCl \\
MgCl_2 & + & Na_2V & = & MgV & + & 2MaCl
\end{array}
$$

The first column represents the various forms of hardness that may be found in water. When any of these are placed in contact with sodium verdite, an exchange is made as shown in columns 3 and 4. The calcium and magnesium are retained by the verdite in exchange for part of its sodium. As shown in column 4, the hardness is wholly replaced by sodium, no insoluble salts are formed and the water leaves the verdite 100% soft.

After all of the exchangeable sodium in the verdite has been replaced by calcium and magnesium, it is necessary to regenerate the verdite by replacing the calcium and magnesium with fresh sodium. This is accomplished by placing a solution of common salt (sodium chloride) in contact with the verdite. An exchange is then made that is just the reverse of the one that took place during the softening operation. The regeneration is explained by the following equations:

$$
\begin{array}{lllllll}
CaV & + & 2NaCl & = & Na_2V & + & CaCl_2 \\
MgV & + & 2NaCl & = & Na_2V & + & MgCl_2
\end{array}
$$

After regeneration the solution remaining in the softener contains chlorides of calcium and magnesium and some sodium. This solution of chlorides is then washed out of the bed and the verdite is again ready for use.

Briefly, a complete cycle of operation consists of a period in which the verdite is softening water, exchanging its sodium for hardness—during which time the sodium is being used up—followed by a period of regeneration in which the sodium is stored up in the verdite for the subsequent softening period. After softening and before regenerating, the bed must be loosened up to insure perfect contact of the brine solution with all of the verdite. This operation is commonly called backwashing. After regenerating and before softening, the chlorides left in the bed must be washed to waste with fresh water. These two operations, backwashing and washing to waste, while of great importance to successful operation, are merely incidental to the main operations of the cycle, namely, softening and regenerating, in which the chemical activity of the verdite is brought into play.

The most common method of handling verdite is in closed steel tanks, operated under pressure in much the same manner as pressure sand filters. The flow of water or brine solution through the verdite is controlled by a simple arrangement of piping and valves located on the outside of the tank.

The entire operation of preparing the brine solution, backwashing, regenerating and washing out the brine, is easily accomplished in less than an hour. During this time it is not necessary for the operator to remain at the softener as his attention is required only at such times as the control valves are operated.

Boiler Compounds

The two preceding methods of removing the difficulties of scale forming substances is by treating the water before it enters the boiler, but if these methods are not used, then the water must be treated within the boiler itself, while it is in action.

Generally, the unusual substances in water can be retained in soluble form or precipitated as mud by adding caustic soda or lime. This is especially desirable when the boilers have small interior spaces.

It is necessary to have a chemical analysis of the water in order to fully determine the kind and quantity of the preparation to be used for the above purpose.

All secret compounds for removing boiler-scale should be avoided.

Scale in Boilers

Scale deposits in boilers may be formed by two methods, (1) by direct deposition on evaporating surfaces, and (2) by mechanical attachment of scale particles already out of solution and in the form of suspended matter.

In the case of the first method, the water becomes super-saturated with calcium and magnesium salts, especially in the film of water directly at the evaporating surface, which as a result are deposited directly as crystals at this point. Crystals once formed may grow in size or new layers may be deposited so as to form a compact and crystalline mass.

By the second method or mechanical attachment, particles of scale-forming salts which have been formed in the water as a result of temperature or supersaturation are mechanically attached to heating surfaces due to the impingment of these finely divided particles or by the settling out of this suspended material which in turn may bake to a solid mass.

Scale deposits formed by both methods may be found in the same boiler, depending upon the rate of evaporation and temperature of heating surfaces.

In considering further the details of this action it becomes necessary to differentiate between the solubilities of sulphates and carbonates in a boiler water. Calcium and magnesium carbonates are held in solution by carbon dioxide gas and are therefore present in a water supply as bicarbonates. When water is brought to the boiling point, the gas is driven off and the normal carbonates are rendered insoluble to a point equivalent to their normal solubilities at the temperature involved. For this reason these salts are referred to as temporary hardness.

On the other hand, calcium sulphate is not rendered insoluble at elevated temperatures until it has concentrated up to a point of its maximum solubility at the given temperature. For this reason it is called permanent hardness.

Calcium carbonate being only slightly soluble in water at 212° F. is partially thrown out of solution in the heater or feed lines and tends to form deposits at these points and also in the boiler near where the feed water enters. These deposits are as a rule soft and granular, but will cause considerable trouble unless corrective measures are taken.

As the water temperature increases, its capacity for carrying most dissolved salts increases, but since the water is evaporating and concentrating, maximum solubility is soon reached. Thereafter, the carbonates will be going into the solid phase at all times, either building scale by direct deposition or forming suspended matter which may become mechanically attached to heating surfaces.

Even though calcium carbonate is slightly more soluble at higher temperatures, the rate for formation of the solid phase is much more rapid than the tendency to redissolve. The slow rate of solution is due to the fact that in all cases the boiler water is saturated with this salt.

Another scale encountered with some waters containing a substantial amount of silica in solution is of the magnesium silicate type. These formations may also be produced in connection with the indiscriminate use of silicate of soda compounds with some waters, especially those of low mineral content. These types are especially objectionable due to the great difficulty of removal. Various percentages of silica may also be found in scale deposits because of suspended matter in the boiler feed supply. Oxide of iron is an important constituent where corrosion is encountered. Under some conditions calcium hydroxide is found, and if present in sufficient quantity results in a compact and crystalline structure.

Boiler Compound Treatment

Treating boiler water to bring about a rapid and more complete precipitation of scale-forming salts and to cause the resulting suspended matter to be of such a form as to be readily removed as a sludge is the function of feed water treatment within the boiler.

In furnishing a treatment to meet specific water conditions, the nature and amounts of scale-forming salts together with operating data must be considered.

In preparing treatment, carefully selected organic reagents must be made use of when the data at hand indicates this specific. The colloidal action of certain of these reagents is especially desirable in the presence of lime and magnesium salts, being absorbed by these salts as they become insoluble, thus preventing the building up of crystals. This action takes place at the evaporating surfaces as well as throughout the boiler water itself and functions continuously, provided the treatment is applied uniformly to the feed water.

Suggested Rules for the Care of Feed Water (A.S.M.E.)

The treatment of boiler feed-water is a specialized branch of chemical engineering. The average operating engineer is not qualified to undertake this phase of the work.

Consequently, in all cases where feed-water treatment is necessary, boiler-plant operators should place their problems in the hands of competent technical specialists, abiding by their advice.

All boilers using feed waters containing calcium sulphate, combinations of sodium chloride and magnesium sulphate, magnesium chloride or sodium or magnesium nitrates, organic acids or mineral acids, should be inspected for scale, or corrosion, or both. Boiler operators should watch their raw-feed supply to guard against the possibility of corrosive elements becoming mixed with the water.

To protect the main supply pipes and pumps during periods of acidity, slacked or commercial hydrated lime containing a high percentage of calcium oxide or soda ash should be fed continuously into the suction pipe, at the source, to make the water slightly alkaline.

Rain water is corrosive, and especially so when it comes from roofs of buildings near manufacturing centres. In such cases it will contain more or less sulphur dioxide in addition to carbon dioxide, oxygen and other corrosive agents, making its use dangerous unless proper correctives are applied.

Distilled water may be corrosive on account of the oxygen and carbon dioxide content, therefore, special care should be taken that these gases are removed if found in objectionable quantities.

No materials should be used for the prevention of scale, corrosion, and priming without an exact understanding of their composition, the nature of the objectionable materials in the feed water to be removed, and the influence the resulting products and unnecessary substances in such materials may have in causing unsatisfactory operating conditions.

Graphite should be used with caution in painting shells and other interior surfaces as it tends to choke up connections to draft regulators and steam gauges.

Kerosene should not be used in boilers for any purpose as it is likely to leave behind inflammable gases which have caused dangerous explosions in the past on the introduction of naked lights into the boiler.

Heater equipment aids in precipitation of impurities, therefore it is advisable to raise the temperature of the feed water as high as is consistent with local plant conditions.

Where gas corrosion is definitely established and it is difficult to maintain the feed water entering the boilers at a minimum of 200 deg. F., and all other means have been exhausted, it is recommended that a live-steam booster connection be used under control of a thermostat, in which case a temperature recorder should be attached and used and a relief valve be placed and set so as to prevent the building up of excessive outlet pressures.

Where open heaters are used, these should be well vented to the atmosphere for carrying off corrosive gases. A separator should be provided for removing any oils that may exist in the exhaust steam for heating the water, and blow-down connections of ample size should be provided for discharging solid materials that may settle from the water.

When boiler water shows the excessive formation of scale or the effects of excessive corrosion, appropriate methods should be adopted for the prevention of these conditions, and such tests and treatments as are directed by the supervising engineer be performed.

Where the correct internal treatment of feed water with chemicals causes accumulating chemical precipitates to interfere with the full delivery of clean steam, the chemical treatment of such a water should be made in separate equipment, outside the boiler, or as directed by a competent chemical engineer.

Where feed waters are chemically purified in equipments external to boilers, such equipments should be of ample size to permit the maximum precipitation and separation of natural, suspended, scaling, and corroding materials from the feed water before such a water enters the feed equipments and boilers.

Proper supervision should control the operation of any water softener.

Where treatment of feed-water is required, the recommended procedure to obtain the best results and greatest assurance of safe operation is the daily sampling and testing of feed and blowdown water, and of condensate from steam mains and surface condensers at the plant.

These tests are in turn to be checked by a qualified water chemist or steam engineer at frequent intervals and advice as to blow-downs and change in treatment is to be given when necessary.

In cases of severe priming and foaming, it is best to consult an experienced water-purification engineer about a remedy to be applied.

Where scale is being removed from boiler by the treatment of feed-water, it should be done under proper supervision so as not to bring the scale down too fast as it may accumulate on the sheets and within the tubes, causing bagging and blistering of these parts. The chemicals for this purpose should be increased very slowly and the effect observed through tests of the blowdown water for excess chemicals.

In such cases the boilers should be taken out of service frequently for cleaning the rows of tubes exposed to the fire in water-tube-type boilers and for cleaning the shells of fire-tube types.

Care should be used to prevent the entrance of oil into a boiler as it will collect in clots on the heating surfaces causing bagging or rupture.

Where there is a possibility of oil entering the feed water through the use of condensed steam, provision in the way of suitable filters or chemical treatments should be made for its removal. Additional precautions should be taken in this removal through the location of suitable traps and drips on the exhaust-steam lines.

Flow Meters

Without proper measuring instruments it is impossible to operate a plant intelligently and allocate to the different apparatus that go to make up the plant, the cost of operation of each. An estimate can be made of the total cost of operation and the total output, but there is no way of arriving at whether or not each piece of apparatus is economical or wasteful. The economy of the plant may suffer due to some one part which should be operated differently or replaced entirely, but cannot be discovered owing to the lack of proper measuring instruments.

In a factory made up of different departments each using steam, water and gas delivered from a central power house, one foreman may be very extravagant in their use, while the

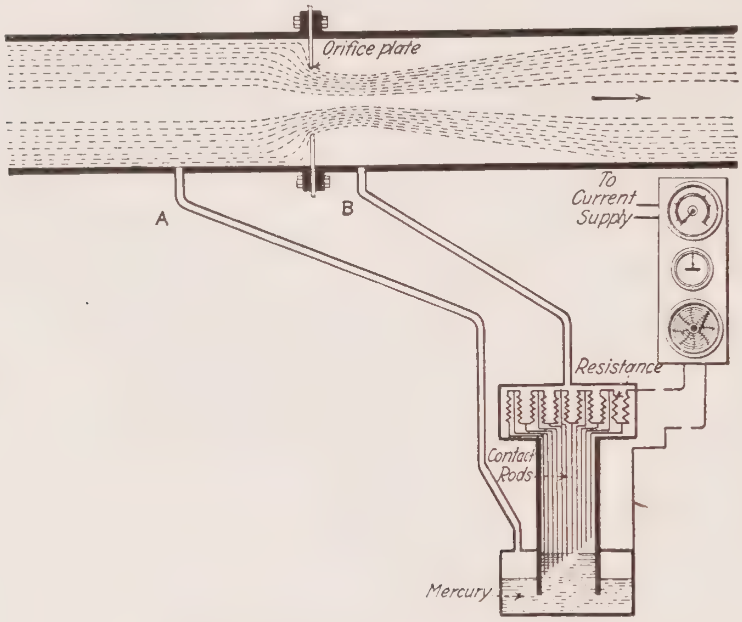


FIG. 44. Republican Flow Meter Connections to Steam Line.

others may be saving. Unless some system is employed to measure the quantities distributed to each department, the negligence of one individual which cannot be detected will affect the whole plant unfairly.

The following subject matter covers only one of several classes of steam-flow meters, the Republic electric-resistance type.

The installation consists of a thin plate of monel metal with a circular opening smaller than the pipe, in which the plate is inserted between a flanged joint, as indicated in the diagram, Fig. 44. The contraction of the moving steam produces a drop in pressure, which is greatest at some point beyond the orifice. This difference in pressure, called the differential pressure, bears a certain relation to steam velocity. To transmit the differential pressure, a ⅜-in. pipe is tapped into the steam line on either side of the orifice. After passing through a valve, each pipe enters a small reservoir O, Fig. 45, which acts as a condenser and maintains an equal column of water in each pipe leading to the meter body.

In the diagram, Fig. 45, it will be noted that A represents the high-pressure or leading pipe and B the low-pressure or trailing pipe The mercury in the meter body shown in the diagram rises, touching the contact rods one after another as the differential pressure rises. This cuts out, one after another, the resistance coils, and the resulting current in the circuit is measured, in this instance by an integrating watt-hour meter, a recording ammeter and an indicating ammeter.

The meters measure electrical energy directly, but are calibrated in terms of pounds of steam per hour at a definite pressure and quality.

The construction of the meter body is shown in the phantom view, Figure 46. Two valves A and B close the connection between the meter body and the steam main. A union joint at the lower end of the valves serves to disconnect the meter body from the piping.

The pipe A, on the left when looking at the front of the meter, connects to the leading side. The right hand connection B goes to the trailing side. The two pipes are joined through a seal C, which is a U-shaped connection partly filled with mercury. The seal projects against the loss of the main body of mercury at D. When a surge occurs with a higher differential pressure than the mercury column can resist, the mercury in the seal C is forced into the water compartment at E and allows the water to blow through as long as the excessive pressure exists. As soon as the differential pressure becomes normal, the mercury returns

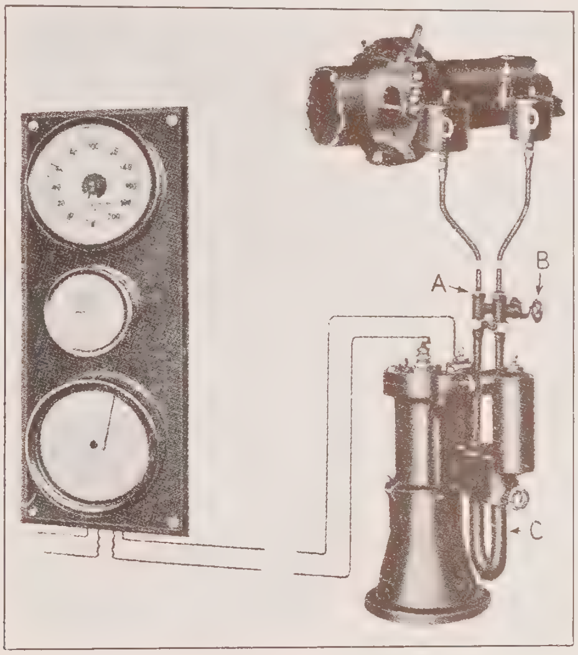


FIG. 45. Republican Flow Meter Connected up.

to the seal. A valve F between the two water compartments is opened should it be necessary to equalize the pressure on the mercury columns for a zero check or to fill the connecting pipes with condensed steam by circulation. As will be noted in the phantom view, the leading pipe A connects to the mercury well D and the trailing pipe to the annular space around the contact chamber J. As the differential pressure increases with the steam flow, the higher pressure in the well forces the mercury up into the contact chamber. The space above the mercury is filled with transformer oil to prevent the mercury and contact rods coming in touch with the dissolved gases in the water, which would invite oxidation.

Venturi Meter

Another instrument used for metering the flow of a fluid through piping is the Venturi meter.

The Venturi meter consists of two parts—the tube, through which the water flows, and the recorder, which registers the quantity of water that passes through the tube.

The tube takes the shape of two truncated cones, Fig. 47, joined in their smallest diameters by a short throatpiece. At the up-stream end and at the throat there are pressure-chambers, at which points the pressures are taken.

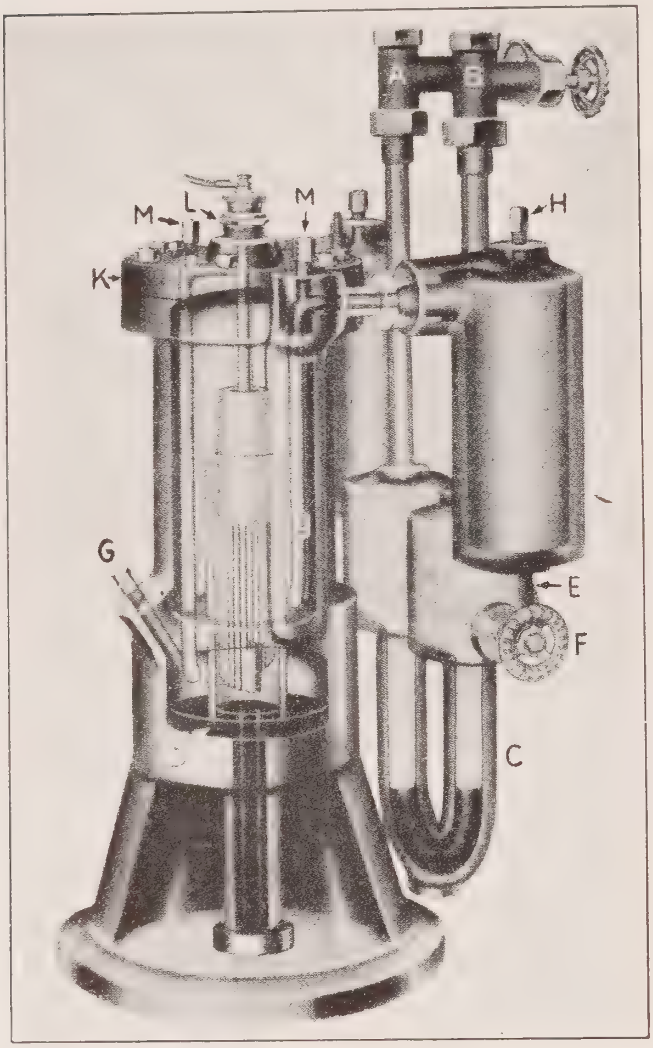


Fig. 46. Phantom View of Republican Flow Meter.

The action of the tube is based on that property which causes the small section of a gently expanding frustum of a cone to receive, without material resultant loss of head, as much water at the smallest diameter as is discharged at the large end, and on that further property which causes the pressure of the water flowing through the throat to be less, by virtue of its greater velocity, than the pressure at the up-stream end of the tube, each pressure being at the same time a function of the velocity at that point and of the hydrostatic pressure which would obtain were the water motionless within the pipe.

The recorder is connected with the tube by pressure-pipes which lead to it from the chambers surrounding the up-stream end and the throat of the tube. It may be placed in any convenient position within 1,000 feet of the tube. It is operated by a weight and clockwork.

The difference of pressure or head at the entrance and at the throat of the meter is balanced in the recorder by the difference of level in two columns of mercury in cylindrical

receivers, one within the other. The inner carries a float, the position of which is indicative of the quantity of water flowing through the tube. By its rise and fall the float varies the time of contact between an integrating drum and the counters by which the successive readings are registered.

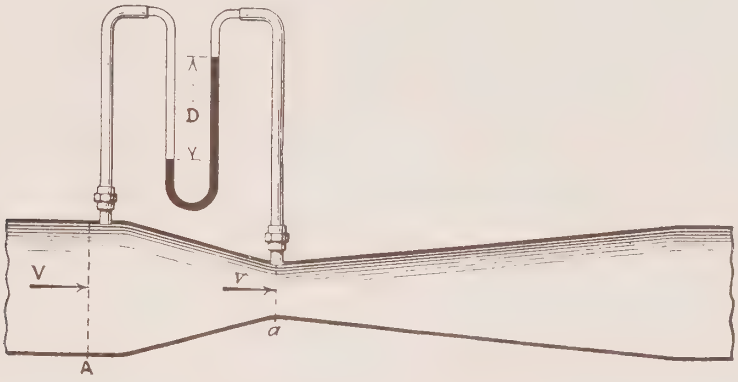


Fig. 47. The Venturi Meter.

The Pitot Tube

The Pitot tube, Fig. 48, is used for measuring the velocity of fluids in motion. It consists of two tubes inserted into the pipe conveying the fluid, one of which has the plane of the orifice at right angles to the current, to receive the static pressure plus the pressure due to impact; the other has the plane of its orifice parallel to the current, so as to receive the static pressure only. These tubes are connected to the legs of a U tube partly filled with mercury, which then registers the difference in pressure in the two tubes, from which the velocity may be calculated.

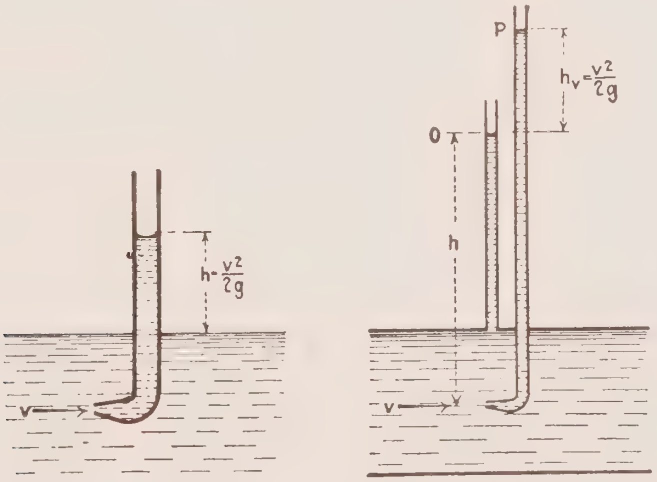


Fig. 48. Pitot Tube.

The Cochrane Metering Heater

The Weir V-notch water meter as applied to a Cochrane heater:

By comparing the records of the metering heater with coal weights it is possible to

determine the evaporation per pound of fuel and to detect inferior fuels, inferior methods of firing, improvements in efficiency from cleaning soot and scale off heating surfaces, or from repairing baffles, settings, etc. An obtainable standard of efficiency once being demonstrated, the meter serves as an indicator to show whether or not this efficiency is maintained regularly in daily operation.

The Cochrane Metering Heater, Fig. 49, is the Cochrane open feed water heater with the addition of a V-notch Weir and a recorder for measuring the water supplied to the boiler. The water falling from the trays is collected and led to a still water chamber, from which it overflows through a V-notch into the outflow chamber supplying the boiler feed pump. A float resting upon the surface of the water in the still water chamber carries a stem passing through a gland directly above the centre of the float. The recorder case is located just above the gland and the float stem enters the bottom of the case through a vapor seal and connects with a cable wound over a drum. The drum is mounted upon a spindle which also carries a cam plate. A groove cut in the cam plate engages a pin on a travelling carriage and the cam is so shaped that the carriage is moved equal distances for equal increments in the rate of flow through the notch. A pin supported by the carriage inscribes upon a chart wound upon a clock-driven drum, thus keeping a record of the rate

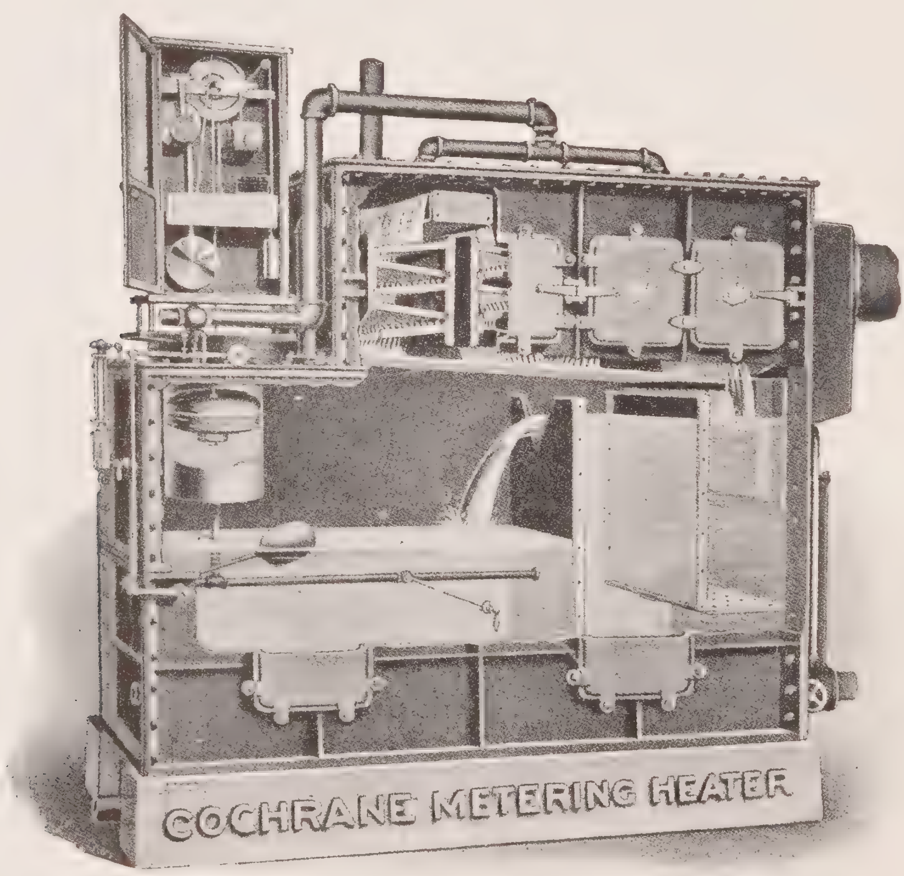


Fig. 49. Cochrane Metering Heater.

of flow. An integrator train, also suspended from the carriage, bears upon the face of an aluminum disk driven by the same clock which propels the chart drum. When the float is in the position corresponding to zero flow, the driving wheel of the counting train rests upon the centre of the aluminum disk and receives no motion. At any other position it receives motion in proportion to the flow and the counting train thus registers the total flow. The clock which drives the integrator disk and the chart drum is of the weight-driven pendulum type, of ample power and having good time-keeping qualities.

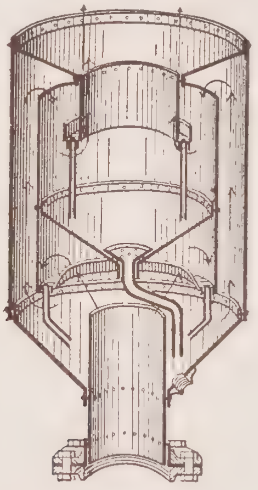


FIG. 50. Exhaust Head.

Exhaust Head

When engine exhaust or other steam is not used but allowed to go to waste in the atmosphere, it is generally piped up through the roof of the building. If this pipe has no covering the moisture from the steam as well as oil and grease, will fall to the roof, polluting not only it but everything in the surroundings. To overcome this trouble it is usual to place on the pipe outlet an apparatus known as an exhaust head. Fig. 50 illustrates one type of exhaust head. Its action is much the same as the steam separator described elsewhere, that is, the steam is caused to suddenly change direction of flow, whereby the water and oil is separated from the steam and drops to the bottom of the separator, from whence it is drained off by a suitable pipe.

Engine-Cylinder Sight Feed Lubricator

The general arrangement of a double-connected hydrostatic sight-feed lubricator is shown in the illustration, Fig. 51, in which the body of the lubricator is partly cut away so that its internal construction and operation may be understood. The body of the lubricator contains cylinder oil D and water E. The water is supplied from condensation of steam admitted from the engine steam supply pipe R through the connection AA and gathered in the condensing chamber C. When the valve B is open, the condensate in C gravitates through a vertical pipe to the bottom of the lubricator where the hydrostatic pressure of

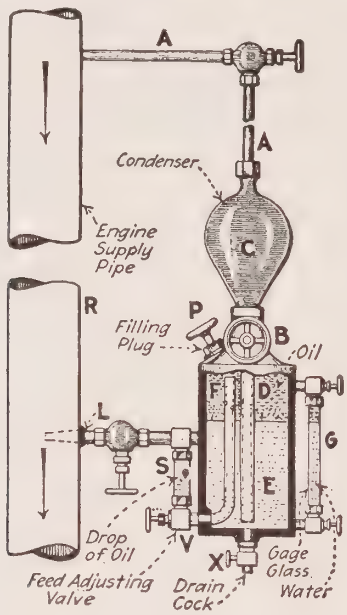


FIG. 51. Engine Cylinder Sight Feed Lubricator.

the water in C or connection A, aided by the steam pressure in R, exerts an upward pressure on the oil. The level of the water E is shown by the gauge glass G.

The total upward pressure exerted by the water E, forces the oil out through the bent pipe F, open at its upper end near the top of the oil chamber, and thence is discharged through the regulating valve upward through water in the sight-feed glass S and delivery pipe L into the main steam pipe R. The delivery pipe L should be extended for some distance into the main steam pipe, as indicated by the dotted lines, and usually is provided with perforations or some form of nozzle for breaking up or atomizing the oil as it is delivered. When the valve V is closed and the valve of L is opened, the sight-feed glass S becomes filled with water formed by condensation of steam entering the connection L.

To fill the lubricator with oil, first close valves B and V and then open the drain cock X and remove the filling plug P. When all water E is drained out, close the drain cock X, pour in the oil at P and replace the filling plug.

For proper operation of the lubricator the chamber C must be full of water or the oil will be broken up by admission of steam to the water space E. In case B has been left open or sufficient time has not been allowed for condensate to fill C, the lubricator should be completely emptied and permitted to cool with the valves B and V closed. Then, after refilling replace plug P and with S filled with water, open B and adjust V to the desired rate of feed indicated by drops of oil rising in S. The lubricator should be started and stopped with the engine. Just after the lubricator has been refilled, it is difficult to adjust a constant feed, especially at a slow rate, because the feed is affected by the changes in viscosity of the oil due to changes in temperature.

Oil Filters

Engineers should realize that oil properly applied, circulated and kept clean means smooth running and long-lived engines and machinery, with greatly reduced friction, low

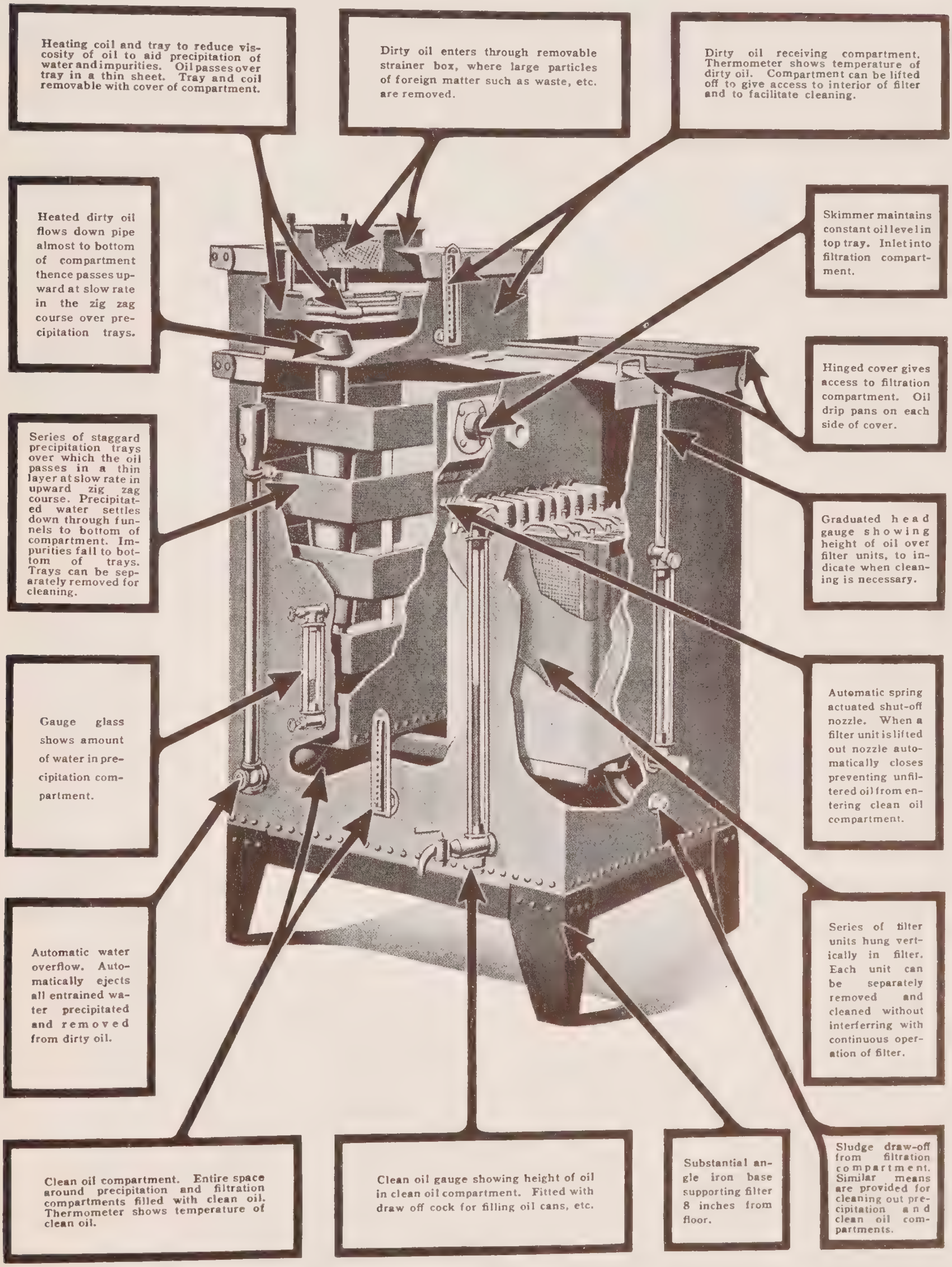


Fig. 52. Oil Filter.

power and fuel consumption, and above all, greatly reduced expense for repairs, shut downs and maintenance.

Mineral oil does not wear out. It becomes unfit for use only because it becomes dirty. Filter the dirt out as fast as it gets in, avoid leakage and wastage, and the oil need never be thrown away.

For cleaning oil, Fig. 52 shows one type of oil filter.

Briefly, the operation of this filter is as follows:

1. The incoming dirty oil is strained, heated to lower its viscosity, and thus cause water and solids to separate readily out of the oil because of the extreme difference of specific gravity between water, solids and the heated oil.

2. The oil flows in a long path at very low velocity over many shallow trays where water and solids are precipitated.

3. After water and heavier solids are precipitated oil passes to filter compartments, passing through many filter units, each covered with closely woven cloth. Every square inch of cloth is effective and under equal pressure.

4. Oil is then stored in clean oil compartment ready for use.

5. When necessary, oil is passed over cooling coils after filtering.

Referring to Fig. 53, dirty oil flows through the screen (2) into the heating tray (3), overflowing at (5) into funnel (6), and down conductor (7) to the baffle, where the oil and water are spread out. Because of the hydrostatic head built up in conductor (7) the oil is forced to take a zig-zag path upwards, passing under and over trays (9, 10, 11 and 12), as shown. The oil then passes out through opening 14 to the filtering compartment. The

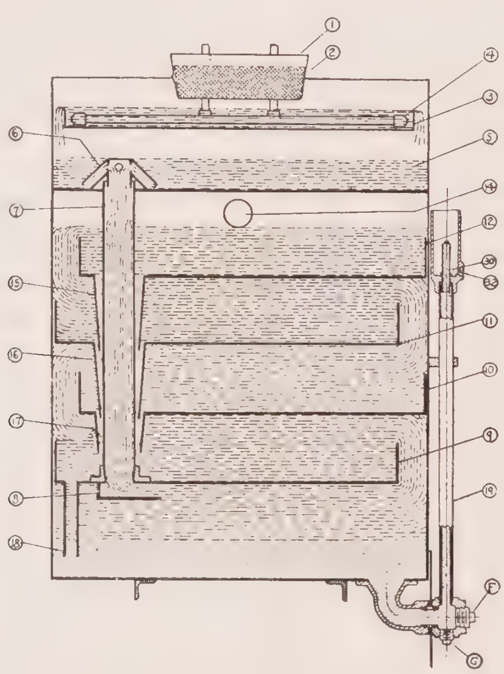


FIG. 53. Sketch showing direction of oil flow in Filter.

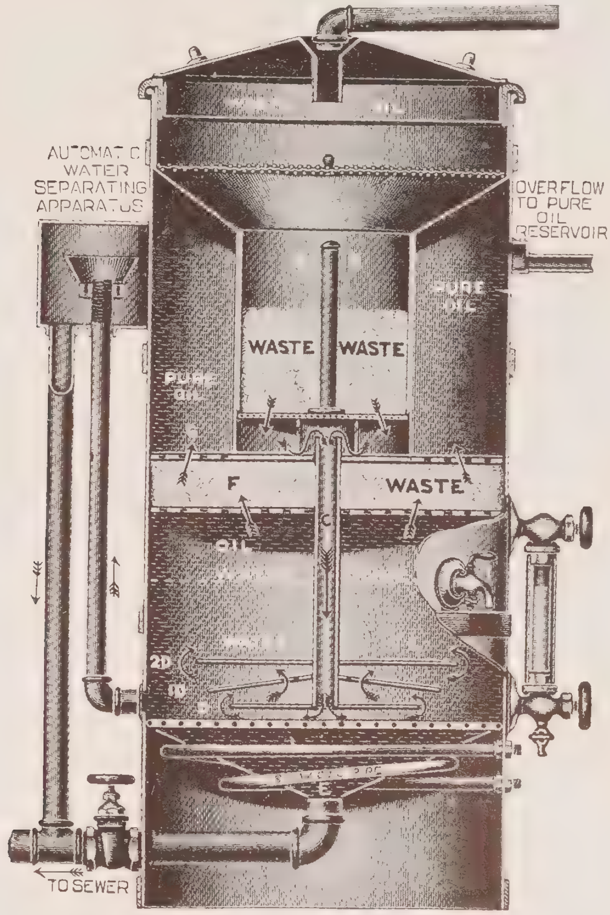


FIG. 54. Another Type of Oil Filter.

galvanized sheet iron trays are supported on legs, fit snugly into the precipitation compartment, and are provided with handles so they may be lifted out conveniently for cleaning when necessary.

The water in the bottom of the precipitation compartment is ejected automatically by the adjustable water-overflow tube (9). This water-overflow arrangement is in effect simply a U-tube wherein the column of water in pipe (19) balances a column in the precipitation compartment made up largely of oil and partly of water. As the oil is lighter than the water, the top of tube (30) is a little lower than the overflow level of the oil in the precipitation compartment. So as more water is precipitated out of the oil and the water level rises in the bottom of the precipitation compartment, one leg of the U-tube becomes over-balanced because it is made up of a greater proportion of water and less of oil. The over-balanced water in the top of the column then flows over into nipple (30) out through 32 until the two legs of the tube are balanced again, thus automatically maintaining proper water level in the precipitation compartment.

Fig. 54 shows another type of oil filter. In it the oil entering at the top passes through the waste contained in the centre chamber, from where it passes downward through the

pipe "C", is heated by the steam coil and flows upward through the water contained in the lower portion of the tank. This water forces the oil through the waste "F" into the pure oil compartment, from which it is drawn off and re-used. The water is discharged to the sewer through the automatic water separator, shown on the left-hand side of the cut.